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Ceramic Abstracts

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PRINCIPLES OF HEAT FLOW IN POROUS INSULATORS*

By H. W. Russell

Abstract

An approximate theory of the thermal conductivity of porous materials is given. The effect of pore size and shape is discussed.

I. Introduction

In all uses of refractories, including those which are primarily structural, their thermal conductivity is an important property. It is not the intention of this paper to point out the advantages to be secured by the use of insulation, but rather to examine and analyze that fundamental quantity known as conductivity as it applies to certain materials.

All insulating structures are porous; they contain voids, commonly filled with air. In brick, to which this discussion particularly applies, the voids are either pockets or cells, more or less spherical in shape, or recesses between particles or granules of the solid. The conductivity of such structures will depend upon the conductivities of the solid and of the pores, and upon the size, shape, and distribution of the pores. To predict exactly the conductivity of a brick from these factors is probably impossible. A reasonable approximation is, however, possible, and may serve, not to replace experimental values, but to explain them.

II. Brick with Spherical Pores

Consider first the case of brick with spherical pockets, such as are formed by "bloating" or by burning out combustible particles. Assume as an approximation that the pores are cubes, all of the same size and with solid walls of uniform thickness, as shown in Fig. 1. The principal justification of this assumption is the belief that such a brick, if it could be made, would not be greatly superior or inferior as an insulator to a similar brick with spherical pores.

Assume that the isothermal surfaces are planes. By the laws of conductors, in series and in parallel, and simple though somewhat lengthy mathematics, the conductivity of the brick is found to be given by the following formula:

$$\frac{K_b}{K_s} = \frac{P^{2/3} + \frac{K_a}{K_s}(1 - P^{2/3})}{P^{2/3} - P + \frac{K_a}{K_s}(1 - P^{2/3} + P)} \qquad (1)$$

Where K_b = conductivity of brick.
K_s = conductivity of solid.
K_a = conductivity of air space.
P = porosity, as a fraction.

III. Pores between Solid Particles

Next consider the case of brick in which the pores are the recesses between granules. Here assume as an approximation that the granules are solid cubes all of the same size, separated by layers of air of uniform thickness. The structure is thus the reverse of the first case. This assumption is not very sound as the granules in any real structure can not be separated, but must touch each other. They will, however, touch in a limited number of points. For this ideal structure, the conductivity is given the same type of equation, the first equation being modified by replacing P by $(1 - P)$ and interchanging K_s and K_a.

Now the porosity, P, is the total volume of the pores in unit volume of the brick and does not depend upon the size of the individual pores. Hence both of the above equations show that the conductivity of the brick is independent of the pore size, for pores sufficiently small that their conductivity is independent of size. It then follows as a rough approximation that the equations hold when the pores are of various sizes.

It is not easy to see directly from the equation just how the conductivity of the brick varies with porosity and with the conductivity of the solid. Figure 2 shows in graphical form these relations. Along the bottom is the porosity, the ordinates are the relative conductivity of the brick, its conductivity divided by the conductivity of the solid. The upper set of curves is for cubical pores with solid walls, the lower set is for solid cubes surrounded by air. The different curves are for different values of the ratio of the conductivity of the solid to the conductivity of air.

* Presented as part of the Symposium on Heat Transfer through Refractories and Insulation in Industrial Furnaces at the Annual Meeting, American Ceramic Society, Cincinnati, Ohio, February 15, 1934. Received July 18, 1934.

It is worthy of note that for the first case, concerning hollow cells with solid walls, the conductivity of the brick decreases almost linearly with an increase in porosity. This is the same as saying that the conductivity increases linearly with the density.

For the second case, insulators made of granular material, the curves show a rapid decrease at low porosities. For granules in contact with one another the porosity can not be greater than about 50%, though it can be greater for fibrous insulators, such as asbestos or glass wool, to which the above theory might conceivably apply. While there is no doubt that the theory predicts too low values for granular insulators, it does appear that a granular insulator should have lower conductivity than a cellular one of the same material and porosity.

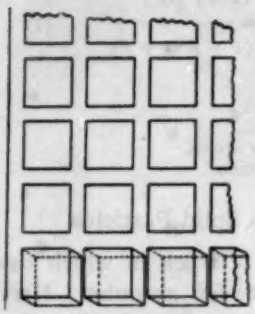

FIG 1.—Types of porous structure assumed.

While it should again be emphasized that these equations or curves are not intended to give conductivities without the necessity of experimental measurements, let us apply them to a definite case.

IV. Conductivity of Bloated Clay Brick

Consider the conductivity at 85°F of cellular brick made by bloating clay and having an experimental conductivity of 1.5 B.t.u. Let its porosity be 81%. At this temperature the conductivity of air, K_a is 0.179 B.t.u./hr./sq.ft./°F/-in. There is scant information on the thermal conductivity of the solid matter of brick at zero porosity. If we assume a conductivity 50 times that of air or 8.95 B.t.u./hr./sq.ft./°F/in., we get a value which is of the right order of magnitude. Now going to the curve we find that at 81% porosity, with a solid of conductivity 50 times that of air, the conductivity of the brick is 0.16 times that of the solid. This gives 1.42 B.t.u./hr./sq.ft./°F/in. when the measured conductivity was 1.5 B.t.u./hr./sq.ft./°F/in., a test of the assumed conductivity for the solid as well as of the theory.

Now consider another brick of the same weight and the same porosity, but let the walls themselves be porous, having a porosity of 5%. The conductivity of the walls is then 0.95 times the conductivity of the solid or 8.50 B.t.u., etc. The brick may now be considered as one having a porosity of 80% and the walls, a conductivity 47 times that of air. From the curve, this brick has a conductivity 0.17 times that of the walls, or 1.44 B.t.u. This agrees with the first calculation and indicates that the conductivity depends upon the true porosity alone and that microscopic pores in the walls do not change the conductivity.

Consider, as probably more plausible, that the walls are of a granular nature. Then from the second set of curves the conductivity of the walls will be only 0.55 times that of the solid or 4.92 B.t.u., etc. Thus the walls have a conductivity only 27 times that of air. The first set of curves shows then a conductivity of the brick of 0.18 times that of the walls, or 0.85 B.t.u., etc.

If now the porosity of the cell walls is decreased, for example, by firing at a higher temperature, the conductivity of the brick will increase accordingly.

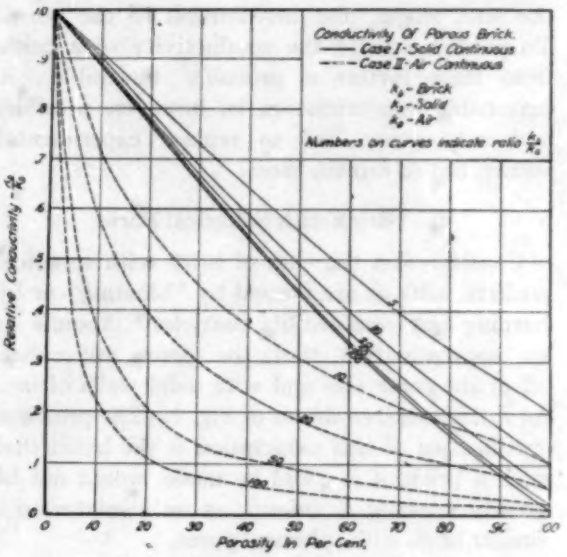

FIG. 2.—Conductivity of porous brick.

For insulators having not too large pores, at ordinary temperatures, evidence has been presented for the following conclusions: (1) Thermal conductivity decreases with increased porosity. (2) For uniform pore size the conductivity is independent of the pore size. (3) Conductivity of material with solid as the continuous phase (spherical pores) is greater than for ma-

terial with air as the continuous phase (granular or fibrous solid) when both have the same porosity. (4) For spherical pores, the size distribution of the pores has little effect on the conductivity. (5) If the solid is partly granular in nature, any means by which the granules are brought into closer contact will increase the conductivity, if the total porosity is unchanged.

V. Conductivity of Solid and of Air Spaces

The treatment and formulas given apply for all temperatures if the conductivities of the solid and of the pores at the temperature in question are used. That the conductivity of

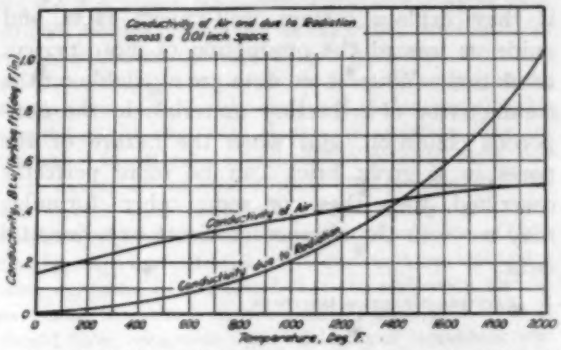
Conductivity of Air and due to Radiation across a 0.01 inch Space
Conductivity of Air
Conductivity due to Radiation
Temperature, Deg. F.

FIG. 3.—Effect of temperature on the conductivity of air, and on the conductivity due to radiation across a 0.01 inch space.

solids varies with temperature is well known, but each solid is a law unto itself and its conductivity is not subject to analysis. Information on the thermal conductivity of nonmetallic solids in the nonporous state is scant, but it is clear that in general the conductivity increases with temperature, though certain materials with a high conductivity show the reverse.

The conductivity of air spaces can be analyzed to yield considerable information. Motion of air, leading to heat transfer by convection, is negligible for air spaces up to about 1/4 inch wide. In porous brick, not hollow brick, the air spaces are commonly much smaller than this. In brick with high permeability air currents can flow up the warm face, across the top, and down the cold face. Where convection is present the conductivity will depend upon the direction of heat flow, being greater for heat flow up or horizontal than for heat flow downward.

In the absence of convection, heat will be transferred across a pore only by true conduction in the air and by radiation. These two processes are additive, so that the effective conductivity of a pore will be the sum of the true conductivity of air and the apparent conductivity due to radiation.

The apparent conductivity due to radiation is defined as rate of heat transfer by radiation per unit area divided by the temperature gradient, and can be expressed in the form

$$K_r = 4\sigma A_{12} T_m^3 x \qquad (2)$$

Where σ = radiation constant (0.173×10^{-8} B.t.u. ft.$^{-2}$ hr.$^{-1}$ (°F)$^{-4}$).
A_{12} = a constant depending upon emissivity and geometry of surfaces of air space.
T_m = temperature °F absolute.
x = width of air space.

Note that while K_r satisfies the definition of conductivity, it explicitly depends upon temperature and distance. For nonmetallic materials, A_{12} may be taken as approximately 1 and we may write

$$K_r = 0.00692 \frac{(T_m)^3}{100} x \qquad (3)$$

At 40°F and a width of 0.01 inch, $K_r = 0.008$ B.t.u., etc., negligible as compared with the conductivity of air of 0.165. But with a thickness of 0.2 inch, the conductivity due to radiation is equal to that of air, or the apparent conductivity of the air space is doubled. Also with an 0.01-inch air space a raise in the temperature to 900°F gives a conductivity due to radiation of 0.16 B.t.u. At the same time the conductivity of air has become 0.36 B.t.u., etc.

Figure 3 shows the conductivity of air and the conductivity due to radiation for 0.01 inch thickness for temperature up to 2000°F.

VI. Value of Small Pores

It thus appears that for low temperatures and small pores the conductivity of the pores is that of air alone. Even for relatively large pores the conductivity of air alone is satisfactory for ordinary temperatures. But as the temperature increases the radiation becomes more effective with large pores, so that the conductivity of material with large pores increases more rapidly than for material with small pores. For conditions where the conductivity of the pores is dependent upon their size, the formula for the conductivity of brick holds only when the proper conductivity is assigned to the particular pores.

For low conductivity at high temperatures it is thus important that, in addition to the porosity

being high, the pore size should be as small as possible. There is a limit to the thinness which the cell walls may have, governed to some extent by the fineness of the grog in the brick. Hence large pores are necessary to secure extremely high porosity, and the gain in porosity is offset by a corresponding increase in the apparent conductivity of the pores.

Granular insulators are peculiarly suitable for use at high temperatures. While high porosities can not be secured, the conductivity is lower than for cellular material of the same porosity. Furthermore, the pores tend to be small, yielding a low apparent conductivity of the pores. Lampblack is possibly the best high-temperature insulator and is a material of this class.

VII. Effect of Permeability

Porosity is commonly accompanied by permeability, because of which gas may pass through the brick. Such a flow of gas represents a loss of fuel, regardless of which direction it flows, but this phenomenon should be regarded as separate and distinct from conduction. As brick wall structures will be permeable not only through the brick itself, but through the joints, infiltration can best be controlled by an impermeable outer coating or shell.

Again, because of permeability, furnace gases may diffuse into the walls. This replacement of the air of the pores by furnace gases may slightly lower the apparent conductivity of the pores. Carbon dioxide at high concentration has a conductivity half that of air. The furnace gases may also deposit carbon in the pores and thus change the conductivity.

As previously mentioned, at high permeabilities natural convection may take place, increasing the conductivity of the brick. While it is not profitable to attempt to formulate even approximately the effect of convection on conductivity, it is known that the apparent conductivity due to convection depends upon the temperature gradient. It is remotely possible that this may explain certain cases where conductivity has been reported to be dependent upon rate of heat flow; no other known mechanism will explain these cases.

VIII. Conclusion

The formulas for the determination of conductivity are applicable to any case of aggregates consisting of two phases by letting P represent the volume fraction of the phase whose conductivity is represented by K_o. Clay-graphite and bonded silicon carbide are common examples of such material. Formulas relating to such cases are to be found in the literature. These formulas are intended for cases where the conductivities of the two phases do not differ as greatly as for solid and air, and they fail to predict that for lowest conductivity the continuous phase should be the low-conductivity material.

In the present stage of our knowledge it is probably not advisable to attempt extensive calculations of thermal conductivity of porous materials. The formulas will serve their purpose if they explain certain well-known facts and guide us toward the production of more perfect insulation. When more data are available on the conductivity of refractory materials in the nonporous condition, and when the nature of the pores in a given brick can be more perfectly described, then these or some other formulas may serve in the absence of direct experimental data.

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DISCUSSION

J. L. Finck: The subject of radiation, which Dr. Russell has introduced is, I think, of far more importance than we have considered it heretofore. The assumption which Dr. Russell makes that the emissivity is practically unity is, I suppose, quite reasonable from our present knowledge and available data on emissivities. I have found in experiments at approximately room temperatures that an appreciable amount of radiation may pass through fibrous materials. Since radiation increases as the fourth power of the absolute temperature, it may be the prevailing factor at high temperatures. If we are to make real progress in the development of high-temperature insulation, we should extend our studies on the total emissivity at high temperatures of various materials, oxides of metals in particular. The literature is poor in data of that sort. We may find that many materials have emissivities quite different from unity. In addition to a study of the size and distribution of air cells within insulation brick, we should also give some thought to the emissivities of the surfaces surrounding these air spaces.

R. B. Sosman: Dr. Russell mentioned lampblack as the best insulator known. The so-called thermatomic carbon is even better. It is the best high-temperature insulator I know of. I believe that this quality of thermatomic carbon was first observed by Dr. Northrup.

A. E. R. Westman: In Dr. Russell's formula we assume, of course, that no heat is transferred through the refractory by radiation; that the radiation is completely

absorbed. I think the question has arisen as to whether some radiation does not go right through the refractory.

I should like to know whether anyone in the audience has any information regarding the transparency of refractory materials at high temperatures.

R. H. HEILMAN: I ran some emissivity experiments a short time ago in which I used a very bright copper surface which was specially selected for brightness. I obtained values slightly less than 0.10 for emissivity. Then I coated the bright copper surface with a very thin coating of clear lacquer and, of course, that immediately brought the emissivity value up, but the interesting point was that the emissivity dropped as the temperature increased with the clear lacquer, whereas the emissivity increased with the bright copper surface. This drop in emissivity indicated that some radiation came through the lacquer. The decrease in emissivity was no doubt due to the fact that at the higher temperatures the wave-lengths most strongly emitted became shorter and could, therefore, more readily penetrate the very thin lacquer film. In other words, we were getting radiation from the surface of the copper plate as well as the surface of the lacquer, and this would indicate that with thin films radiation does get through. In a former experiment, a polished silver surface, having an emissivity value of approximately 0.02, was coated with lampblack. The coating was thick enough that with careful observation no reflection of light could be seen from its surface. However, when emissivity tests were run, it was found that the emissivity for the particular lampblack surface was as low as 0.75 when it should have been near 0.98. Additional lampblack was then deposited on the surface of the polished silver plate and it was found by measurement with a microscope that a thickness of approximately 0.003 of an inch was necessary to obtain an emissivity coefficient of 0.98 or to prevent the radiation coming through from the polished silver surface.

F. A. HARVEY: The statement was made in the Refractories Division that magnesite brick at open-hearth temperatures are practically transparent.

R. B. SOSMAN: It is a well-known fact that quartz and vitreous silica are transparent to several ranges of wave-lengths in the ultra-red (heat radiation).

H. W. RUSSELL: I would like to ask Mr. Sosman if he has given any thought to the matter of whether that radiation which gets completely through the material would be considered as a part of the conductivity of the material. It is probably measured when the conductivity of glass is measured as a legitimate part of the conductivity.

R. B. SOSMAN: No, I should say it is not properly to be considered a part of the conductivity.

F. A. HARVEY: We have been hearing about the conductivity due to radiation and conductivity due to convection. I think possibly part of the trouble we find in conductivity measurements has been due to the lack of definiteness in our terms. The phenomenon is complicated, and may involve all three types of heat transfer (conductivity, radiation, and convection). Should we not use the established conception of these terms?

R. B. SOSMAN: When the engineer speaks of "radiation losses," he often means convection taken together with radiation. When the physicist says "radiation" he means radiation only, as it is transmitted through a vacuum, and is therefore not always speaking of the same thing as the engineer.

H. W. RUSSELL (written discussion): That confusion arises from the use of the expression "conductivity due to radiation," as pointed out by Mr. Wilkes and Mr. Harvey, can not be denied. But it is a useful concept, and coining a new word for it would only add to the confusion. A closely analogous difficulty in alternating current electricity has been met by coining the word "admittance."

Conduction is a means or mechanism of heat transfer. Conductivity is a physical magnitude, "a physical constant." The conductivity of a material is a number secured by a certain experiment, useful in predicting certain facts of heat flow. In very few of the materials whose conductivity we measure is the mechanism of heat transfer conduction alone.

If a hollow evacuated space were tested in the apparatus by the methods used for measuring conductivity, a number would be secured. This number would be the conductivity due to radiation.

AN APPARATUS FOR MEASURING THE THERMAL CONDUCTIVITY OF REFRACTORIES AT HIGH TEMPERATURES*

By J. L. Finck

Abstract

An apparatus is described for measuring the thermal conductivity of refractories at temperatures up to about 2000°F. The theory and method of test are discussed in detail and results are given on a light refractory insulating brick and also on a silica fire brick and dense clay fire brick.

I. Introduction

The problem of measuring thermal conductivities of refractories at high temperatures involves, first, the problem of maintaining a well-defined type of heat flow through the test specimen. Usually the type of heat flow which is desired is one which has geometric simplicity, as for example, normal flow through a flat slab or radial flow through a sphere or cylinder. For any selected type of heat flow, an exact mathematical equation may be developed which expresses the thermal conductivity in terms of the density of heat flow, the dimensions of the test specimen, and the temperature gradients within the specimen. If the equation of heat flow applies to a steady state, it is essential that the system be in thermal equilibrium. Having selected the type of specimen and the equation for calculating thermal conductivity, the experimental problem consists in realizing in the laboratory those particular conditions to which the formula applies. This phase of the problem is intrinsic also in conductivity measurements at room temperature.

A second phase, particularly characteristic of high-temperature work, is the choice of suitable materials for the building of the apparatus. Such materials must maintain their form and must offer good electric insulation for the heating elements and thermocouples at the high temperatures. The apparatus must be so designed as to permit readily the replacement of heating elements and other parts which may fail from time to time.

This paper includes a brief description and a study of the behavior of an apparatus designed for thermal-conductivity measurements at temperatures up to about 2000°F. In this work much attention was devoted to a study of the character of heat flow and its effects on the calculated conductivity. Data are given on a light insulating refractory brick and also on a silica fire brick and dense clay fire brick. The latter two were selected by Committee C-8, A.S.T.M., as specimens for test for the Symposium on Heat Transfer.

II. Description of Apparatus

A sketch of the apparatus is shown in Fig. 1. Figure 2 shows the apparatus partly assembled, and Fig. 3, the control board. Part *A*, Fig. 1, is a circular, cup-shaped Alundum disk which holds the center heating element, *a*. The current and potential leads from this heater emerge through a small hole at the center bottom of *A*. Part *B* is also of Alundum and is in the shape of a flat, cupped ring, which contains the heating element, *b*. This will be referred to as the edge or guard heater. *G* is a third Alundum part which contains a heating element, hereafter referred to as the bottom heater. All heating elements are made of nichrome wire, insulated with porcelain fish-spine beads. The bottom heater is covered by an Alundum plate, *F*, and a cast nichrome plate, *J*, $^3/_8$ inch thick. *C*, *D*, and *E* are Alundum rings or short tubes which support the center and edge heaters.

Over the center heater is a cast nichrome cover, *H*, which is $^3/_8$ inch thick and has an apron which covers the sides of *A*. Similarly, the edge heater is covered by a cast nichrome cover, *I*, $^3/_8$ inch thick, with aprons covering the inner and outer sides of *B*. The nichrome castings function as isothermal surfaces over the center and edge heaters. Plate *J* also serves as an isothermal surface. The purpose of the aprons on *H* and *I* is to eliminate temperature irregularities

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* Presented at the Symposium on Heat Transfer, at the Annual Meeting, American Ceramic Society, Cincinnati, Ohio, February, 1934, sponsored by Committee C-8, A.S.T.M.

This investigation was started while the writer was connected with the U. S. Bureau of Standards, and was completed at the J. L. Finck Laboratories.

Received August 7, 1934.

at the sides and within the $^1/_8$-inch gap between the center and edge heaters. Nichrome was selected for this purpose because it is the most practical metal which can withstand oxidation and at the same time is of a comparatively high thermal conductivity.

In Fig. 1, *e*, *e* represent holes $^1/_2$ inch deep drilled into the nichrome. Platinum-platinum

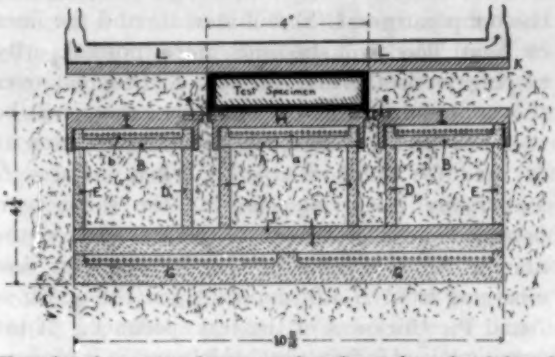

FIG. 1.—Apparatus for measuring thermal conductivity of refractories at high temperatures.

10% rhodium differential thermocouples, 0.3 millimeter in diameter and insulated by fine porcelain tubing, are placed within these holes to indicate the temperature difference across the gap. The Alundum tube, *C*, carries a similar set of differential thermocouples to indicate the temperature gradient between the center and bottom heaters.

The test specimen is cut in the form of a flat, circular disk. It may have the diameter of *H* or may extend over *H* and *I*. The test specimen carries on its flat surfaces platinum-platinum 10% rhodium thermocouples 0.1 millimeter in diameter. These couples are set in fine grooves on the surfaces and serve to measure the temperature of each face.

Over the test specimen is another cast nichrome plate, *K*, $^3/_8$ inch thick, which serves as an isothermal surface directly over the upper surface of the specimen. Above *K* is a flat, hollow brass plate, *L*, through which water is circulated. This water plate may be placed in direct contact with *K*, as shown in Fig. 1, or may be raised any desired height above *K*, and the intervening space between *K* and *L* may be filled with insulating material, such as diatomaceous earth. This makes it possible to maintain a comparatively small temperature difference across the test specimen, the remaining temperature drop being supported by the insulation between *K* and *L*. This method has been practiced consistently, since it makes it possible to approximate to a mathematical differential ΔT across the specimen; the significance of this will be discussed later.

All hollow spaces within the apparatus and around the specimen, except those in close proximity to the heaters, are filled with loose diatomaceous earth, and a generous layer of insulation is provided over the sides and bottom.

III. Theory and Method of Test

The formula which applies to a steady, normal heat flow through a specimen such as is selected in this work is

$$k = \frac{Q}{S} \cdot \frac{d}{\Delta T} \qquad (1)$$

Where Q = total heat flowing normally through area, S.
d = thickness.
ΔT = temperature difference across the specimen.
k = thermal conductivity.

The total heat generated in the center heater is equal to the electric power input, EI.

The conditions under which equation (1) can be used for calculating the conductivity are (*a*) that all the heat generated in the center heater,

FIG. 2.—Apparatus partly assembled, with test specimen in position ready for test.

and this heat only, shall flow upward into the test specimen; (*b*) that the flow of heat shall be normal through the entire height of the specimen; (*c*) that the system shall be in thermal equilibrium; and (*d*) that ΔT shall be small.

Consider conditions (*a*), (*b*), and (*c*). To satisfy (*a*), the heat flow must be reduced across

the gap between the center and edge heaters and between the center and bottom heaters to a quantity which will be small compared to the total heat generated in the center heater. This is accomplished by adjusting the currents in the edge and bottom heaters. The high thermal resistance between the respective heaters permits this adjustment to be made quite easily. Should

FIG. 3.—Observation table and control for the conductivity apparatus.

there be any residual temperature differences between the respective heaters, corrections to the quantity, Q, can be applied if the conductivities of diatomaceous earth and Alundum, and the dimensions of the apparatus are known. Such corrections have always been applied. In general, they amounted to 1% or less of the heat generated in the center.

These adjustments made and thermal equilibrium established, the heat generated in the center will flow upward into the surface of the test specimen, except for a small fraction which will flow into the gap and then turn upward. This latter heat flow, indicated in Fig. 4*a* by the dotted lines, may be applied as a small correction term, which will be considered later. Neglecting it for the moment, it must be proved experimentally that condition (*b*) is satisfied. Suppose that the surface of H, Fig. 4*b*, is at a temperature higher than the isothermal surface, I, and also higher than the entire surroundings. Further, suppose the test specimen to have a conductivity equal to or greater than the surrounding diatomaceous earth. Point (3), Fig. 4*b*, for instance, under these conditions, will be at a temperature lower than (2). Heat will flow from points (1) to (2) and from (2) to (3). Even if the center line (1)–(2) represents a line of normal heat flow through the specimen under the conditions described, it is to be expected that all other lines of heat flow, represented by the dotted lines, should diverge from H and I.

If the temperature of I is brought to that of H, the temperature at (3) will increase and the lines of heat flow will become more normal. By placing an isothermal surface, K (Fig. 4*c*) over the upper surface of the specimen, there will be still less divergence, since the temperatures at (2) and (3) are now equal. When surfaces H and I are isothermal and at the same temperature and K is also an isothermal surface, the amount of divergence of the lines of heat flow emerging from H will depend upon the width of I and the thickness of the test specimen. If the specimen is of infinitesimal thickness, it is obvious that the heat flow will be normal even if I were

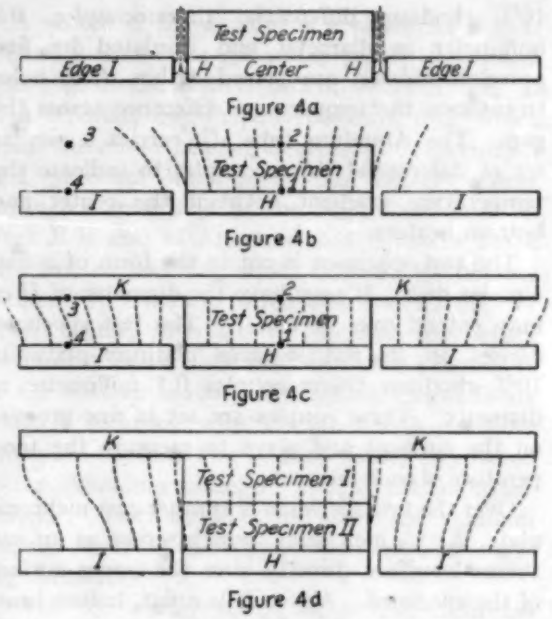

FIG. 4.

very narrow. For a given edge width, there will be some maximum thickness of specimen which may be tested in this apparatus without obtaining an appreciable divergence of lines of heat flow.

Suppose two specimens, made of similar materials and of approximately equal thickness are

placed one over the other, as shown in Fig. 4*d*, and tested simultaneously. Each specimen carries its own thermocouples so that a separate set of data may be obtained on each one. The quantity, Q, of equation (1) is the heat generated in H, corrected for heat losses, and this quantity must be used in calculating k for each of the specimens. If there is any divergence of the lines of heat flow, the *actual* total flow through specimen I will be less than through specimen II. Therefore, the *calculated* conductivity for I will be greater than that for II. If these two specimens are reversed and specimen II is placed on top of specimen I, the calculated k for the upper specimen again is greater than that for the lower. If there is no appreciable divergence of lines of heat flow, the two calculated k's should be equal to each other, and should equal the true conductivity of the specimens. If the two calculated k's differ by, say 10%, because of the divergence of the lines of heat flow, the actual divergence for the bottom specimen may reasonably be assumed to be of the order of 5% and its calculated k will be equal to the true k to about this same order. Thus there is some measure of the accuracy of the conductivity, insofar as divergence of lines of heat flow is concerned, if specimen I were tested by itself under the conditions shown in Fig. 4*c*. The error in k due to the errors in the measurements of Q, S, d, and ΔT in general does not exceed 2 or 3%. Of these four quantities, the one which offers the greatest difficulty is the measurement of ΔT, or the absolute temperature of the two surfaces of the test specimen, particularly for tests at high temperatures. The reason is that at the high temperatures there is some electrical leakage from the heaters on to the thermocouples. This can be overcome, however, by breaking the current for a very short interval and observing ΔT. Numerous tests have shown that there is no appreciable change in temperature during the short interval that the current is cut off.

One remark must be noted as to the quantity of heat flowing across the gap. It was stated above that some of the heat generated at the center flows from the edge, as shown by the dotted lines in Fig. 4*a*. This heat, under conditions of normal flow, will not pass through the specimen if the latter covers only the center area, H, but will pass through the surrounding diatomaceous earth. The edge heater, I, will also lose some of its heat from the edge facing the gap. Of the total heat flowing through a column of diatomaceous earth, whose area is equal to the total area of the gap, it is assumed that one-half will be contributed by the center heater and the other half by the edge heater. Therefore, the quantity, $\pi r \cdot \Delta r \cdot \Delta T \cdot k_1/d$, must be subtracted from Q, where r is the radius of the center heater, Δr, the average width of the gap, k_1, the thermal conductivity of diatomaceous earth at the corresponding mean temperature of the test sample, and ΔT and d are the same as in equation (1). This correction term usually amounts to much less than 1% of Q.

Let us now consider condition (*d*). This is important, since in some types of apparatus tests are made where the entire temperature drop from that of the heater down to room temperature is supported by the test specimen itself. We wish to know what error, if any, is introduced by such a procedure.

The thermal conductivity, as defined in physics, is equal to

$$k = \left(\frac{\partial h}{\partial l}\right) \Big/ \left(\frac{\partial T}{\partial n}\right) \qquad (2)$$

where $(\partial h/\partial l)$ = density of heat flow across a given boundary.
$(\partial T/\partial n)$ = the temperature-gradient at that boundary.

k, may be called the true conductivity at that boundary and will, in general, be a function of the temperature.

For a homogeneous material and for normal heat flow through a specimen such as has been considered above, we may write

$$(\partial h/\partial l) = Q/S.$$

Where Q and S are the terms appearing in equation (1) write

$$\int_0^d \left(\frac{\partial h}{\partial l}\right) \delta n = \frac{Q}{S} d = \int_0^d k \left(\frac{\partial T}{\partial n}\right) \delta n = \int_{T_1}^{T_2} k \delta T \qquad (3)$$

where T_1, T_2 = the respective temperatures of the cold and hot sides of the specimen.

We may assume that the true conductivity, k, is expressed as

$$k = a + bT + cT^2 \qquad (4)$$

where a, b, c = constants.

Define the mean conductivity, k_m, by the equation

$$k_m(T_2 - T_1) = \int_{T_1}^{T_2} k \delta T = \frac{Q}{S} d \qquad (5)$$

Note that k_m is identical with k of equation (1), where $\Delta T = T_2 - T_1$. The question is when $T = T_m = \frac{1}{2}(T_1 + T_2)$, will k, as given by equation (4), be equal to k_m, or expressed mathematically, will the following equation be valid:

$$k_m = a + bT_m + cT_m^2 \quad (6)$$

To consider this, write

$$k_m(T_2 - T_1) = \int_{T_1}^{T_2} k\delta T = \int_{T_1}^{T_2} (a + bT + cT^2)\delta T \quad (7)$$

Integrating and simplifying terms, we have

$$k_m = a + bT_m + \frac{4}{3} cT_m^2 - \frac{1}{3} cT_1T_2 \quad (8)$$

If $c = 0$, we have

$$k_m = a + b\,T_m \quad (9)$$

and the true conductivity, k, corresponds to k_m, for $T = T_m$ regardless of the magnitude of ΔT. However, if $c \neq 0$, the value of k will not be identical with the true k at $T = T_m$. In this case, write k_μ as the true k at $T = T_m$, and

$$k_\mu = a + bT_m + cT_m^2 \quad (10)$$

$$k_m - k_\mu = \frac{4}{3} cT_m^2 - \frac{1}{3} cT_1T_2 - cT_m^2 = \frac{c}{12}(\Delta T)^2 \quad (11)$$

This means that the larger the value of ΔT, the greater will be the deviation of the calculated from the true conductivity. This deviation depends, of course, also on the value of c. Although in the tests reported in this paper, the values of c are sufficiently small so as to make this deviation about 2% of k for the low conductivity material when $\Delta T = 2000°$F, the writer has, on previous occasions, tested insulating refractory brick where the value of $\frac{c}{12}(\Delta T)^2/k$ amounted to as high as 22% for $\Delta T = 2000°$F.

IV. Tests on Materials of Low and High Thermal Conductivity

To make a complete study of the operation and behavior of the present conductivity apparatus, tests were made on materials of low as well as high thermal conductivity. In the first case, since the heat flow through the specimen is small, it should be known whether the edge and bottom heaters can be adjusted sufficiently well so as to reduce the correction terms to a small value. In the case of a material of high conductivity, the adjustments of the edge and bottom heaters do not usually have to be very close. In this case, however, other difficulties arise, such as that of contact resistance between the specimen and the isothermal surfaces. In both cases, we wish to know how thick a sample can be tested with reasonable accuracy.

For the low conductivity material, two specimens of the same grade of a light insulating refractory brick were selected. They are referred to as samples A and B. Table I gives the data on each sample and also the results of conductivity tests. These samples were tested simultaneously, according to arrangement shown in Fig. 4*d* with sample A at the bottom. Each sample carried its own thermocouples. The results are plotted in Fig. 5. It will be observed that the average deviation of the points from the curve is of the order of 5 or 6%. It may be

TABLE I

DATA ON A LIGHTWEIGHT INSULATING BRICK

Sample	Thickness (in.)	Diameter (in.)	Surface area (sq. in.)	Density (lb./cu. ft.)
A	1.021	3.98	12.43	31.8
B	1.013	4.00	12.57	32.0

Sample A in direct contact with center heater; sample B placed on top of A

Sample A				Sample B			
Hot side (°F)	Cold side (°F)	Mean temp. (°F)	k (B.t.u. hr.$^{-1}$ ft.$^{-2}$ deg.$^{-1}$ F in.)	Hot side (°F)	Cold side (°F)	Mean temp. (°F)	k (B.t.u. hr.$^{-1}$ ft.$^{-2}$ deg.$^{-1}$ F in.)
251.2	156.9	204.0	1.203	154.0	70.7	112.4	1.350
444.4	255.0	349.7	1.229	250.5	81.0	165.8	1.358
586.8	330.6	458.7	1.484	335.5	97.9	216.7	1.586
809.6	465.1	637.4	1.412	463.8	108.0	285.9	1.367
933.3	537.8	735.6	1.592	539.8	119.8	329.8	1.491
955.8	549.3	752.6	1.540	550.2	121.5	335.8	1.446
1376.2	1020.6	1198.4	1.872	1016.4	613.0	814.7	1.637
1686.0	1349.1	1517.6	2.116	1342.9	973.9	1158.4	1.920
1901.3	1590.3	1745.8	2.374	1597.1	1254.7	1425.9	2.138

assumed then that the absolute accuracy of these results is of this same order of magnitude.

For high conductivity material, two grades were tested: one was a silica fire brick and the second, a dense clay fire brick. In the case of the

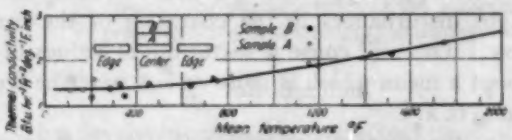

FIG. 5.—Thermal conductivity of a light insulating refractory brick.

silica fire brick two test specimens were prepared, referred to as samples I and II. Table II gives the data on each sample and also the results of conductivity tests. The results are plotted in Fig. 6. A few results were obtained on sample II tested by itself, and they are shown in Table II and Fig. 6. The average deviation of the points from the curve is of the order of 10% or less. The absolute accuracy of these results may then be assumed to be of this same order of magnitude.

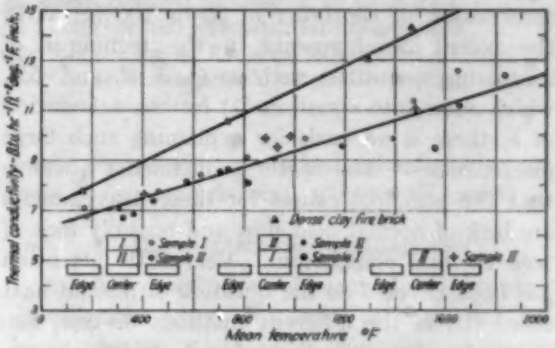

FIG. 6.—Thermal conductivity of a silica fire brick and a dense clay fire brick.

Only one specimen of the dense clay fire brick was tested. The data and results of tests on this specimen are given in Table III and Fig. 6.

TABLE II

DATA ON A SILICA FIRE BRICK*

Sample	Thickness (in.)	Diameter (in.)	Surface area (sq. in.)	Density (lb./cu. ft.)
I	1.009	4.02	12.69	105.4
II	0.990	4.02	12.69	105.6

The following data apply to the tests where sample II was placed in direct contact with the center heater; sample I was placed on top of sample II.

Sample I				Sample II			
Hot side (°F)	Cold side (°F)	Mean temp. (°F)	k (B.t.u. hr.$^{-1}$ ft.$^{-1}$ deg.$^{-1}$ F in.)	Hot side (°F)	Cold side (°F)	Mean temp. (°F)	k (B.t.u. hr.$^{-1}$ ft.$^{-1}$ deg.$^{-1}$ F in.)
236.7	103.8	170.2	7.10	371.5	240.1	305.8	7.06
249.3	108.7	179.0	6.74	392.0	253.0	322.5	6.70
521.8	405.1	463.4	7.75	630.7	522.0	576.4	8.17
686.5	575.2	630.8	8.40	792.3	685.4	738.8	8.60
868.1	763.9	816.0	9.10	972.9	868.8	920.8	8.95
1116.7	974.5	1045.6	9.80	1262.3	1118.1	1190.2	9.51
1558.8	1384.0	1471.4	11.32	1744.9	1570.8	1657.8	11.17
1737.3	1565.6	1651.4	12.58	1924.9	1753.3	1839.1	12.37

The following data apply to tests where sample I was placed in direct contact with the center heater; sample II was placed on top of sample I.

Sample I				Sample II			
Hot side (°F)	Cold side (°F)	Mean temp. (°F)	k (B.t.u. hr.$^{-1}$ ft.$^{-1}$ deg.$^{-1}$ F in.)	Hot side (°F)	Cold side (°F)	Mean temp. (°F)	k (B.t.u. hr.$^{-1}$ ft.$^{-1}$ deg.$^{-1}$ F in.)
484.2	406.6	445.4	7.39	404.2	322.0	363.1	6.85
872.6	760.8	816.7	8.10	759.9	655.2	707.6	8.53
1635.8	1479.2	1557.5	9.46	1468.0	1319.7	1393.8	9.85

The following data were obtained in tests on sample II by itself.

Hot side (°F)	Cold side (°F)	Mean temp. (°F)	k (B.t.u. hr.$^{-1}$ ft.$^{-1}$ deg.$^{-1}$ F in.)
446.0	369.1	407.6	7.66
942.6	835.2	888.9	9.85
989.6	877.5	933.6	9.50
1553.0	1409.2	1481.1	11.02
1039.5	933.6	986.6	9.93

* Star brand silica brick, furnished by the Harbison-Walker Refractories Company for the coöperative study of thermal conductivity.

V. Conclusions

Comparing the results of conductivity measurements made on the same and similar materials by different methods, there are discrepancies, in some cases, of the order of 50 or 100%. With the recent developments in the technique of measuring quantities such as Q, S, d, and ΔT, which enter into equation (1) for the calculation of k, there is no basis for explaining such large discrepancies. The writer is inclined to believe that the principal causes for these discrepancies are lack of normal heat flow and possibly lack of true thermal equilibrium. Very little attention has been devoted to the question of normal heat flow. If, in the different methods of test, isothermal surfaces were introduced wherever necessary to give normal flow, in all probability the discrepancies could be reduced considerably.

TABLE III
DATA ON A DENSE CLAY FIRE BRICK*

Thickness (in.)	Diameter (in.)	Surface area (sq. in.)	Density (lb./cu. ft.)
0.989	3.97	12.39	146

Hot side (°F)	Cold side (°F)	Mean temp. (°F)	k (B.t.u. hr.$^{-1}$ ft.$^{-2}$ deg.$^{-1}$ F in.)
219.0	111.9	165.4	7.79
773.6	674.2	723.9	10.51
1345.1	1245.0	1295.0	13.02
1549.2	1384.0	1466.6	14.29

* Mexko brand fireclay brick, furnished by the A. P. Green Fire Brick Company for the coöperative study of thermal conductivity.

The question of thermal equilibrium arises when tests are made on large specimens, such as sections of wall furnaces. With such large specimens the control of temperatures becomes much more difficult, and measurements of heat flow become very uncertain because of the large heat capacity of the wall. The experimenter can easily be misled by apparent states of thermal equilibrium.

A word about contact resistance between the test specimen and the isothermal surfaces: If the couples used in measuring ΔT are fixed in the isothermal surfaces rather than on the test specimen, it is possible for contact resistance to be added to the thermal resistance of the specimen, and the resultant k will be consistently too low. However, if the surfaces of contact are made reasonably plane and the couples mounted directly on the specimen, there is less likelihood of consistent errors in k in one direction. Slight differences in contact resistance, due to removing the specimen from the surface and then placing it back into position, may cause slight disturbances in the character of the heat flow. This will cause a scattering of values of k about a mean which is more or less near the true value of k.

In the present investigation, the specimens were changed in position quite frequently, and the results as shown above appear quite satisfactory. The reason for the larger scattering of points in the case of the silica fire brick, as compared to that of the light insulating brick, may be due to this effect of contact resistance. The total heat flow through the fire brick was about 5 times that through the insulating brick, and contact resistances in the case of the fire brick were usually a much higher percentage of the total thermal resistance as compared to that for the insulating brick. However, an accuracy of about 10% for fire brick, and about 5 or 6% for insulating brick should be quite satisfactory for all practical purposes.

The temperature range over which conductivity measurements can be made in this apparatus is limited principally by the heating elements, which in this case are of nichrome. The writer has recently built a second apparatus which in general design is the same as the present apparatus, but the heating elements are made of a new type of wire and the isothermal surfaces are made of silicon carbide. Preliminary tests have shown this apparatus to agree closely with the apparatus described in this paper. It is expected that this new apparatus will permit tests to be made up to about 2300 or 2400°F. This apparatus will be described in detail in another paper.

Acknowledgments The writer wishes to take this opportunity to express his appreciation of the interest and many suggestions offered by M. S. Van Dusen of the U. S. Bureau of Standards and to N. Karp, who has assisted the writer in this work at the J. L. Finck Laboratories.

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WASHINGTON, D. C.

INSULATING REFRACTORIES*

By W. M. Hepburn

Abstract

Insulating materials of various types are discussed and their installation in air heaters, carbottom, walking-beam bright annealing, standard, bell-type, and wire patenting furnaces, and glass leers is described. Data on the savings involved in the use of insulating refractories are given. The characteristics of the materials are uniformity of product, shrinkage and spalling properties, physical strength, insulating value, and thermal capacity.

I. Introduction

The development of the refractory insulating brick by the refractory manufacturers marks another advance in furnace construction, which already has proved its value in a variety of applications.

The immediate field which apparently presents the best possibilities for this brick is the heat-treat group, such as the full line of small standard furnaces, the continuous automatic furnaces, both direct-fired and muffle-type of bright annealing and carbottom furnaces. The vitreous enameling furnaces also present a good possibility for this type of lining. Steel-mill equipment would demand further progress in this material before it is accepted to any appreciable degree.

The open-hearths are beyond the temperature limitations of this brick, and soaking pits and billet heaters, with their long continuous period of operation and other factors demanding heavy masonry walls, preclude this type of equipment as immediate prospects for the present brick. The lower temperature jobs such as sheet and pair furnaces and normalizing furnaces require the greatest precautions against any dusting from the arch. Definite assurance against this action will have to be established before this brick will become attractive for these operations.

However, annealing operations in the steel mills present attractive possibilities. The use of an alloy heating element, fired internally by a diffusion-combustion type of burner in conjunction with a refractory insulation in a structure designed for annealing operations, is a particularly attractive development. This construction enables the use of gas atmospheres and accuracy of control, and speeds up the heating and cooling, which represents a marked advance over any type of furnace previously used for this work.

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II. Significant Installations

A brief description of some of the types of installations using this class of materials may serve better to bracket the performance of insulating refractories: (1) air heaters, combustion chamber lining, (2) carbottom furnaces, (3) continuous bright annealer, walking-beam type, (4) standard furnaces, (5) bell-type annealer with diffusion-fired alloy heating elements, (6) wire patenting furnace, and (7) glass leer.

(1) Air Heaters One automobile factory is equipped with thirty-nine gas-fired air heaters, capable of delivering 812,000 cubic feet per minute of air heated from an outside temperature of −20 to 78°F to spray booths in which the automobile bodies are painted. The heaters equipped with butane burners have a capacity of 78,000,000 B.t.u. per hour.

The combustion chambers are lined with refractory insulating brick and have a series of baffles, also of this brick, on which combustion impinges. This use as a baffle exposes all four sides of the brick to the direct action of the combustion.

The refractory insulators attain incandescence quickly each time the control valve opens and they withstand the rather severe combustion conditions very well.

(2) Carbottom Furnaces The stress-relieving carbottom furnace is 60 feet long, 14 feet 6 inches wide, and 17 feet 7½ inches to the spring line of the arch. It is lined with 9 inches of insulating refractory backed up with ¼ inch of asbestos millboard, both anchored to steel panels. The sprung arch is of a catenary design with a rise of 4 feet 10 inches and is constructed of 9 inches of insulating refractory, grouted with a high-temperature mortar.

The doors are of the lifting type and consist of channel frames stayed with horizontal and vertical rods and lined with 9 inches of insulating refractory. The top of each car is protected by 10 inches of insulating refractory with cross-piers of fire brick spaced at 5-foot intervals. Special tile is anchored to the sides of the cars to hold in place the insulating refractory on the car top.

The furnace is fired with natural gas and its thermal efficiency is about 34%.

Only 23.6% of the heat is required to heat up the furnace structure itself, 5% less than that

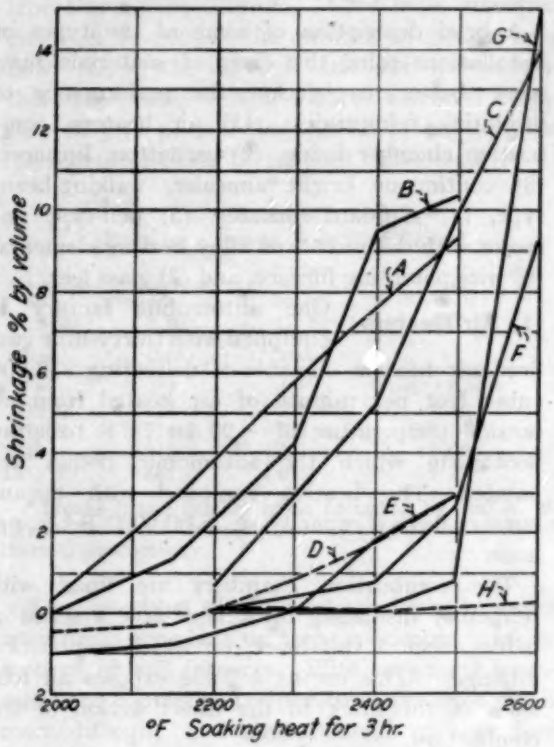

FIG. 1.—Free shrinkage characteristics of refractory insulators.

for the charge, and only 10.3% is lost by radiation.

The total fuel consumed during a representative run was 50,000 cubic feet of 1000 B.t.u. natural gas or 1185 cubic feet per ton of charge, which equals 0.585 cubic feet per pound of steel.

(3) Walking-Beam Bright Annealing Furnace A bright annealing furnace of the walking-beam type for annealing automobile wheel disks at about 1500°F was completely lined with insulating refractory.

The sidewalls and arch of the furnace consist of 4½ inches of insulating refractory brick, backed with 4½ inches of insulating brick. The bottom is constructed of 5 inches of insulating refractory brick and 5 inches of insulation.

According to actual metered tests, the furnace required 138 cubic feet of 3200 B.t.u. gas per hour to hold over week-end periods where the furnace was held at a controlled temperature of 1400°F. When operating at the rated capacity of 2160 pounds per hour at a temperature of 1600°F with a butane fuel consumption of 450 cubic feet per hour, the overall thermal efficiency of the furnace is 40%.

(4) Standard Furnaces Up to the present there has been no failure of linings built of this brick in high-speed muffle furnaces. A number of lower temperature furnaces *i.e.*, oven furnaces and pot furnaces (1500–2000°F) are lined with this brick. There has been excessive spalling in some of the slot forge furnaces.

(5) Bell-Type Annealer The bell-annealing furnace is completely lined with 9 inches of insulating refractory. In addition to permitting fast cycles it also facilitates the handling due to its lighter weight.

(6) Wire Patenting Furnace This furnace is 4 feet wide, 50 feet long, 8 inches spring of arch, and lined with 4½ inches of insulating refractory, 2½ inches of high-temperature insulation, and 1 inch of low-temperature insulation. It is coated with sillimanite cement.

Its capacity is 6000 pounds of No. 12 gage to ⅛-inch diameter wire per hour, heated to 1850°F using 11,000 cubic feet of 385 B.t.u. mixed gas per hour; the time required to bring the furnace from cold to 1850°F is 2 hours.

(7) Glass Leer A direct-fired leer has been placed in operation using insulating refractory as a lining in the high-temperature zones. It is of the continuous wire-mesh belt type and is 6 feet wide (inside width of conveyer) by 75 feet long. It has no muffle, stack, or exhaust fans. The heating is accomplished largely by convection rather than by radiation.

This leer consists of a steel casing lined with insulation, the bottom and sidewalls with 5 inches and 4½ inches, respectively, while the roof construction consists of 6 inches of insulation.

Because of the absence of muffles and by the use of the insulating refractory, the leer can be safely brought up to temperature in a few hours

insuring extreme flexibility and a reduction in fuel by reduced holding rates over weekends.

III. Characteristics of Insulating Refractory

The general accredited advantages of the refractory insulating brick are (1) saving in heat storage, and (2) reduced time in bringing the furnace to temperature.

The above savings are obtained in the intermittently fired furnaces. The general objection to this brick is its higher cost. The first two advantages can easily outweigh the additional expenditure and, in view of the cautious advance in the use of these materials, it is apparent that there are other factors which must be of influence.

As might be anticipated in a material combining insulating and refractory properties, we must expect a compromise between the desirable features of each of the two general classes of materials, insulators and refractories. We must also be prepared to accept the undesirable features of the two general classes.

In general, the insulating properties as indicated by the conductivity data released by the manufacturers are decidedly confusing. Much emphasis has been placed upon this particular property of the materials under discussion, but owing to the many methods employed in determining the values, it is practically impossible to correlate the data. Since conductivity values must of necessity be predicated on the assumption that the material in question is homogeneous and since we know that decided variations exist, conductivity values must be considered relative rather than absolute. Perhaps as accurate a method as any is to base all values on the conductivity of first quality fire brick, modifying the values for any particular material by the ratio of its bulk density to that of fire brick. Such an assumption will, of course, be only a rough approximation but should be sufficiently accurate until such time as a standard conductivity test code is evolved and all materials are tested by the same method.

Regarding the refractory properties of the materials under discussion, a decided lack of emphasis on these properties is apparent. Very little information is available regarding shrinkage, spalling, effect of cement coatings, and such physical properties as crushing strength, both cold and at temperature.

To the furnace manufacturer, complete and accurate information regarding these properties is essential. Of this group, perhaps shrinkage may be considered the most important. When a material having an excessive shrinkage at the temperatures existing in a particular application is utilized, complete failure of the structure is only a question of time and the furnace lining must be replaced.

A number of free shrinkage tests in an oxidizing atmosphere on the various materials have been conducted in order to bracket the useful ranges of temperature in application of the insulating refractory brick. These tests include determinations for free shrinkage at soaking heat for three hours in combination with cement-coated panel tests under the same conditions of temperature. From the data obtained to date, it appears that when the free shrinkage, after three hours at soaking heat, exceeds 1% by volume, cracking invariably appears on the cement-coated panel of similar material. For free shrinkage values of less than 1% the panels show no indications of failure. This condition was observed on all of the eight materials tested to date; thus we believe that it is highly important to select a material for a particular application so that at the highest anticipated temperature the selected material will have a free shrinkage value of less than 1% by volume.

Figure 1 shows the free shrinkage characteristics of the eight brands of refractory insulators tested to date. Bearing in mind that the volumetric shrinkage should not exceed 1%, these eight materials are easily bracketed as to their useful temperature ranges. The following is a brief description of each brand tested:

Brick	Composition	Texture	Bulk density (lb./cu. ft.)	Safe temp. limit (°F)
A	Principally kaolin	Coarse pores	45.7	2040
B	High alumina	Very coarse pores	49.2	2110
C	High alumina	Very coarse pores	49.2	2230
D	Bloated fire clay	Coarse pores	43.2	2320
E	Fire clay	Fine pores	44.4	2350
F	Fire clay	Coarse pores	57.8	2430
G	Kaolin	Very fine pores	33	2500
H	Fire clay	Fine pores	56.7	2600

Additional tests are in progress on four other commercially obtainable materials. Shrinkage tests under a superimposed load of two pounds per square inch are partially completed and are of particular interest in connection with brands

D and E. These two brands are said to contain appreciable quantities of flint clay and, unloaded, show an initial increase in volume before shrinkage begins. Under the relatively small loading of two pounds, the initial tendency to grow is almost entirely suppressed.

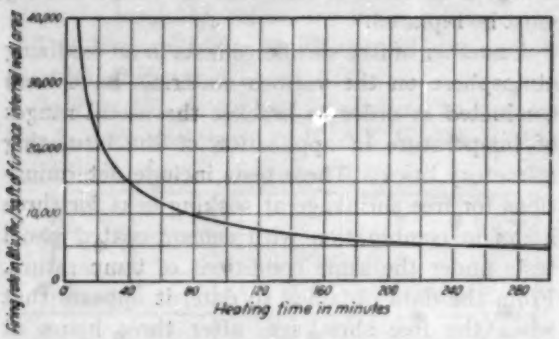

FIG. 2.—Relation between time required to bring furnace to temperature and rate of firing (B.t.u. per sq. ft. wall per hour) for refractory insulator (bulk density 35 lb. per cu. ft.) and natural gas fuel.

From our observations to date, the use of a cement coating on the hot face of the brick has little bearing on safe maximum temperature at which the brick may be utilized. A relatively thin coating, not exceeding $^1/_{32}$ inch in thickness, appears to be the most satisfactory. A thicker coating shows either a tendency to flake off or to pull apart the exposed hot face of the brick. These tendencies are probably a result of the variation in shrinkage and expansion characteristics of the coating as contrasted with those of the brick they are intended to protect. Cement coatings properly selected and applied are undoubtedly useful in protecting the brick against erosion or dusting and decrease its permeability to furnace gases. A cement should not, however, be expected to correct deficiencies inherent in the brick themselves. The temperature suitability of a particular brick will depend upon its composition, its firing temperature, and firing cycle during manufacture.

If an analysis of the proposed application of the refractory insulator indicates the probability of thermal shock, careful attention should be paid to the spalling characteristics of the material selected. The standard air-blast spalling test appears definitely superior to the water-dip test for these materials and should be used for purposes of comparison.

Very little information is available regarding the crushing strength at elevated temperatures. Until uniform testing methods are adopted and the results published, the user may resort to the comparatively crude methods of approximating the relative crushing strength of the various materials by comparing their bulk densities.

(1) Savings The potential saving in fuel may perhaps be best illustrated by means of an example. Let us assume that the furnace in question has an internal wall area of 100 square feet and that the operating temperature is to be 1800°F. Let us further assume that a 9-inch wall of insulating refractory will replace with equivalent heat loss an 18-inch wall of fire brick. We may further assume that the fuel is released in the furnace at the rate of 8000 B.t.u. per square foot of internal wall area per hour.

Attention is directed to Fig. 2 which shows the experimentally determined results obtained on an insulating refractory having a bulk density of 35 pounds per cubic foot. This curve shows the relation between the rate of British thermal units release and the time required for the furnace to attain temperature.

From the curve, the time required to attain temperature with a British thermal unit release

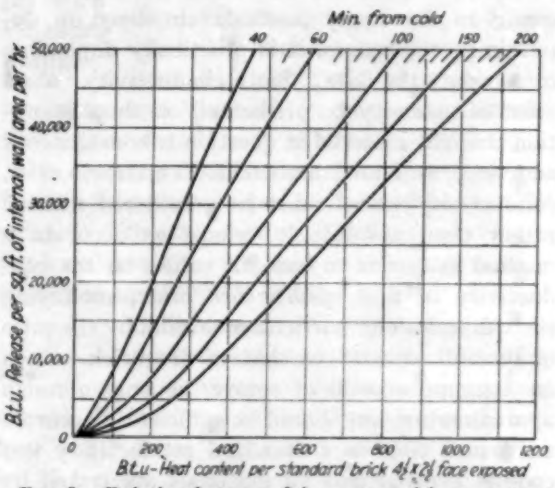

FIG. 3.—Relation between firing rate and heat content per standard brick after firing for 40 to 200 minutes from cold and at constant rate; refractory insulator (bulk density 35 lb. per cu. ft.).

of 8000 is 124 minutes or 2.065 hours. From cold to temperature the furnace will require

$$2.065 \times 8000 \times 100 = 1{,}652{,}000 \text{ B.t.u.}$$

If the furnace had been lined with fire brick, the time required to attain temperature would

have been approximately 6 hours, and the fuel required for the heating-up period would have been

$$6 \times 8000 \times 100 = 4{,}800{,}000 \text{ B.t.u.}$$

The saving in fuel during the heating-up period is 3,148,000 B.t.u. or 65½% of that required for the firebrick lining, and the saving in heating-up time of 3.935 hours represents 65½% of that required for the firebrick lining.

Since, at the end of the heating-up periods, neither of the two walls under consideration is near saturation or thermal equilibrium, the heat storage values may be approximated. The results of actual tests on the lighter wall are given in Fig. 3, which shows the relation between rate of British thermal unit release and thermal capacity. From the curve, each square foot of light wall at the end of 124 minutes contains

$$12.8 \times 240 = 3075 \text{ B.t.u.}$$

Since from purely theoretical considerations the temperature changes penetrate within the refractory insulator and fire brick at the same rates, we may approximate the heat storage in the firebrick wall from Fig. 3. At the end of 360 minutes the heat storage in a 9-inch lightweight wall would be

$$12.8 \times 465 = 5950 \text{ B.t.u. per sq. ft.}$$

Since at the end of 6 hours the temperature at a point 9 inches in from the hot face of the firebrick wall has not risen materially, we may neglect the other 9 inches and multiply the figure for the light wall by the ratio of the bulk densities. This means that each square foot of firebrick wall will contain at the end of the 6 hours heating-up period

$$\frac{121}{35} \times 5950 = 20{,}550 \text{ B.t.u.}$$

The difference in heat storage amounts to 85% of that contained in the heavier wall.

The item of heat storage may be of considerable importance depending upon the nature of the operation to be performed in the furnace. If heat storage is not desirable, the lighter wall has obvious advantages.

In line with new furnace development, the insulating refractories may have an important place. For instance, the lighter linings have many desirable features in connection with special atmosphere furnaces. Here again it may be well to have a thorough knowledge of the requirements to be met. Some of the refractory insulators contain metallic impurities susceptible to attack by the constituent gases usually encountered in furnaces of this type. The most generally objectionable impurities appear to be the various oxides of iron which react with carbon monoxide and hydrogen in a manner to produce disintegration of the brick after a period of exposure.

IV. Conclusions

It would be our opinion that these brick represent a valuable contribution in the method of lining furnaces and will find ever-increasing applications. An accurate knowledge of their present limitation will be the most effective item in insuring their steadily growing acceptance. The manufacturers of these brick should establish accurate standard performance specifications which will enable the various classes of these brick to be used in their proper brackets.

The uniformity of the brick must be more accurately controlled. The relatively thin walls resorted to when using this brick for lining places a far greater risk against failure of any one brick than is the case when using heavy refractory walls.

To the furnace manufacturer the following construction features and operating points are of practical importance:

(1) The thinner and lighter walls made possible through their utilization means a generally lighter furnace, requiring considerably less structural material in the shell. The possible saving in weight is particularly important in small portable furnaces.

(2) For a given rate of firing, a furnace lined with a refractory insulator may be brought up to temperature in from 25 to 35% of the time required for a furnace with a firebrick lining. This point is important where the furnace does not run continuously, such as those which are heated up in the morning and shut down over night.

(3) Owing to the lighter weight of refractory made possible by the use of refractory insulators, the total heat storage in the furnace walls is materially less than in the case of a firebrick lining.

Listed in order of importance, the characteristics of brick we would desire are as follows: (1) uniformity, (2) shrinkage, (3) spalling, (4) physical strength, (5) insulating values, and (6) thermal capacities.

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PHYSICAL PROPERTIES OF SOME INSULATING BRICK*

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Abstract

An investigation of eleven types of insulating brick was made. Physical properties determined included bulk density, porosity, transverse and crushing strength, pyrometric cone equivalent, volume shrinkage at 2300°F, 2500°F, and 2700°F, load deformation at elevated temperatures, and resistance to spalling. A study of the relation between permeability and pressure differential through the various insulating brick is included in the report.

Suggestions for classifying the various types of insulating brick into groups and a critical discussion of formulas for permeability are also given.

I. Introduction

While it is not the purpose of this paper to go into the details of insulation, by way of presenting the data it is desirable to recall a few of the principles involved. Back-up insulators, in a general way, can be divided into high- and low-temperature insulation. Under the former type may be discussed furnace insulation of all sorts and it is with this type of insulation that this paper is primarily concerned. Attempts have been made by some producers to classify furnace insulation further as either high or intermediate temperature products.

The former class usually gives service up to 2400°F and the latter up to 2000°F. A still higher service is claimed for a new class of insulators now coming into wide use. These are called "refractory insulators," "insulating refractories," or "facing refractories." The indiscriminate application of the term "insulating brick" to the three types of products listed above has caused a great deal of confusion.

High-temperature insulation is usually used in a furnace wall behind a facing of fire brick, while the so-called refractory insulation is exposed to the flame in most cases or is faced with a thin layer of refractory cement.

High-temperature insulation, used for back-up purposes, was formerly made only of mixtures of diatomaceous earth and clay. More recently refractory clays with additions of organic matter have been formed into ware for this type of service.

"Refractory insulation" is made of highly refractory clays or minerals precalcined in a large part at least. Sufficient plastic clay is added to the clay or calcine to permit molding the body roughly into shape.

Cellularity of insulating brick may be produced by the following methods: (*a*) burning out of a combustible; (*b*) mechanical cellulation in which the powdered body is aerated; (*c*) the body prepared in slip form and bloated by gas evolved from a chemical reaction; or (*d*) the body prepared in slip form and a stabilized foam developed in it.

With possibly one or two exceptions no attempt is made to produce a brick true to size before firing. The prepared batch is either formed in individual molds by hand or else is extruded from an auger machine. An exception to this method is the use of a soft-mud re-pressing operation by one manufacturer. After forming, the ware is dried and fired as other ceramic ware and, after firing, the crude shapes are accurately sized by automatic cutting devices.

II. The Investigation

The data given in this paper are presented with the view to aiding in the classification of the various types of insulating products. The brands of brick included in this investigation represent the three types of insulation mentioned above, and also include those most widely used at the present time.

Table I gives a description of the materials used, firing temperature, method of manufacture, and service recommendation for each of the eleven brands of brick that were included in the tests.

Table I

Description of Test Brick

Brand A: Clay diatom brick fired to 2500°F; recommended as back-up insulation for temperatures up to 2500°F; porosity partially produced by burning out of combustible; coarse pores.

* Presented at the Annual Meeting, American Ceramic Society, Cincinnati, Ohio, February, 1934 (Refractories Division); also before the joint meeting of the Electrochemical Society and the American Ceramic Society, Asheville, N. C., April 27, 1934. Received June 19, 1934.

Brand B: A brick made from kaolin and fired to 2400°F; recommended as facing refractory, in absence of slag or abrasive conditions, for temperatures up to 2500°F; coarse pores.

Brand C: 100% diatomaceous silica brick fired to 1900°F; recommended for service to 2000°F; pores microscopic.

Brand D: Diatomaceous silica-lime bonded brick fired to 2400°F; recommended as back-up insulation under special conditions up to 2500°F; fine pore structure.

Brand E: High alumina insulating brick fired to 2570°F; recommended as facing refractory for intermittent temperatures up to 2600°F or for constant operating temperatures up to 2500°F; porosity produced by burning out combustible; very coarse pore structure.

Brand F: High alumina brick fired to 2400°F; recommended as facing refractory for temperatures up to 2300°F; porosity produced by burning out combustible; coarse pore structure.

Brand G: Clay brick (part of clay precalcined) made porous by burning out combustible; recommended as a facing refractory; fine pore structure.

Brand H: Kaolin brick (part of kaolin is precalcined) fired to 2600°F; recommended as facing refractory for

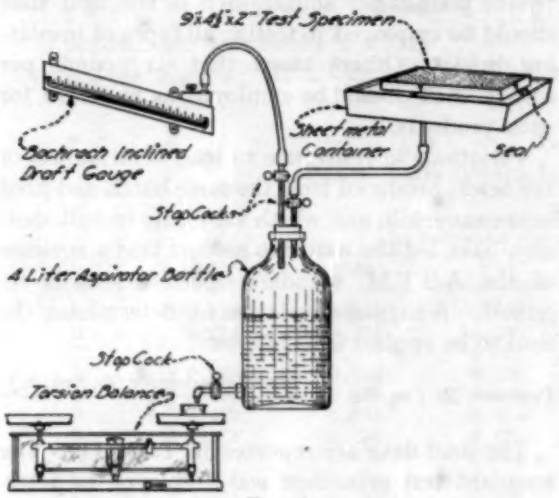

FIG. 1.

temperatures up to 2800°F; porosity produced by burning out combustible and by mechanical cellulation; fine pore structure.

Brand I: Calcined clay brick fired to 2400°F; recommended as facing refractory for temperatures up to 2500°F; porosity produced by chemical bloating; moderately fine pore structure.

Brand J: Calcined clay brick; recommended as back-up insulation for temperatures up to 2000°F; porosity produced by chemical bloating; fine pore structure.

Brand K: Kaolin (part of which is precalcined) brick fired to 2650°F; recommended as facing refractory for temperatures up to 2650°F; fine pore structure.

The procedure employed in determining the physical properties of the brands of brick listed above will be discussed and the test data obtained will be given in the sections that follow.

(1) Bulk Density, Porosity, and Transverse and Crushing Strength

Test values for these properties are given in Table II.

Density values are expressed in pounds per cubic foot. The two extremes are represented by brands G and J. Brand G, as shown in the table, has approximately one-half the weight of a standard fire brick. Brand J, which has a density of about 30 pounds per cubic foot, is very weak, however, and is used only as back-up insulation. The average value for the brands that can be classed as insulating refractories is from 45 to 50 pounds per cubic foot.

NOTE: Test values reported in the tables contained in this manuscript were obtained by following the standard test methods prescribed by the American Ceramic Society and the American Society for Testing Materials, 1930, and suggested test methods for transverse strength, compression, and reheating shrinkage for high-temperature insulation, A.S.T.M., 1933.

TABLE II

DENSITY, POROSITY, AND STRENGTH OF TEST BRICK

Brand	Bulk density (lb./cu. ft.)	Porosity (%)	Transverse strength (lb./sq. in.)	Crushing strength (lb./sq. in.) (edge)	(flat)
A	38.1	77.8	101.2	190	186
B	47.7	74.9	209.2	431	508
C	38.3	79.1	101.2	727	761
D	37.6	80.1	89.4	240	276
E	47.0	77.3	162.2	118	102
F	50.6	76.5	219.5	187	183
G	61.2	68.8	301.2	459	522
H	37.7	81.6	90.7	180	129
I	52.6	74.3	241.2	374	579
J	29.6	85.7	73.8	116	190
K	54.4	67.3	182.0	411	300

Porosity determinations were made in a gas-expansion porosimeter.[1] The brands that can be classified as back-up insulation have an average porosity value of about 80%, while the insulating refractory brands have an average porosity value of about 75%.

Strength tests were made on a Riehle 50,000-pound testing machine. The procedure followed was in accordance with the A.S.T.M. C 93–33 T tentative specifications for insulating refractories. These specifications do not require the test specimens to be capped. The brick are compressed on the flat to a deformation of 5% of the original thickness unless definite failure shall have occurred

[1] E. E. Pressler, "A Simple Brick Porosimeter," *Jour. Amer. Ceram. Soc.*, 7 [3], 154 (1924).

before. The ten brick broken in the transverse tests were used to determine crushing strength both on edge and flat.

The better grades of insulating refractories have crushing-strength values in excess of 400 pounds per square inch. As would be expected, in general the crushing strength on edge is less than on flat. The tests should be made on edge because the results are more indicative of weaknesses in structure of the various brands.

Strength values for brands E and F, where transverse values are considerably greater than crushing values, are contrary to all the accepted theories for the strength of materials. This peculiarity has been checked by several independent investigators working with these two brands of brick.

Values for reheat shrinkage and pyrometric cone equivalent are given in Table III.

TABLE III

FIRING SHRINKAGE AND P.C.E. OF TEST BRICK

Brand	Volume (%) shrinkage at 2300°F	2500°F	2700°F	P.C.E. (cone)
A	0.84	15.68		29–30
B	6.21	18.37	20.60	31–32
C	5.08	7.72		23–26
D	0.83	4.28		23
E	2.76	5.64	13.20	32+
F	7.03	7.81		31
G	1.16	6.78	17.95	31
H	1.39	3.35	3.76	32+
I	0.00	4.57	20.33	28
J	2.96	Fused		20–
K			15.54	32+*

* Values obtained from producer.

The procedure for the shrinkage test suggested by the A.S.T.M. C 93–33 T is as follows:

> The test specimen shall be protected from direct flame or localized heating from direct contact with furnace parts. The maximum temperature to be used shall depend on the material. This maximum temperature shall be obtained in not less than three hours. The maximum temperature shall be held for a period of five hours. The sample shall be left in the furnace until the furnace temperature has fallen at least to 500°F.

It was found to be impossible to reach the maximum temperature in 3 hours. In the test made at 2300°F, this temperature was attained in 5 hours, while the time required to reach 2500 and 2700°F were 7 and 10 hours, respectively.

Brand B showed an excessive amount of shrinkage at 2500°F, the temperature for which it was recommended as a facing refractory. Practically all of the insulating refractory brands showed excessive shrinkage at temperatures above 2500°F. Brand H is the only exception.

The seven brands of brick, recommended as facing refractories at temperatures from 2300 to 2800°F, have P.C.E. values above cone 30, with the exception of brand I. Brand A has an exceptional P.C.E. of cones 29 to 30 for a back-up insulation, since all the other brick falling in this classification have values below cone 26.

There is no standard test procedure for evaluating the resistance of insulating refractories to load at elevated temperatures. Tests made by the manufacturers of these products vary greatly in the loading and procedure employed so that it is practically impossible to correlate their data and to determine the relative merits of the various brick produced. Some manufacturers whose product is particularly resistant to load deformation at elevated temperatures insist that ten or twelve pounds per square inch is the load that should be employed in testing all types of insulating brick. Others assert that six pounds per square inch should be employed as standard for such products.

Variations in resistance to load deformation of fire brick, produced from the same batch and fired in the same kiln and which vary only in bulk density, have led the writer to suspect that a revision of the A.S.T.M. standard specifications is required. A suggested relation for determining the load to be applied is as follows:

$$\text{Pressure (lb./sq. in.)} = \frac{\text{fired bulk density (lb./cu. ft.)}}{5}$$

The load data are reported in Table IV. The standard test procedure was employed in determining the values given in Table IV, *i.e.*, a standard rate of heating $4^1/_2$ hours to the test temperature and held for $1^1/_2$ hours at that temperature.

A study of the values given in the table indicates that most of the brick fail when tested at 2445°F (using 10% subsidence as an indication of failure). Brands C, H, and K are notable exceptions. H and K are recommended, however, for high-temperature service, while C, which contains considerable diatomaceous earth, is recommended merely as a back-up brick for temperatures up to 2000°F.

Data on permeability and spalling resistance are given in Table V. The equipment shown in

Fig. 1 was used to determine permeability values. The sides of the test brick were paraffined and the brick then placed in the metal pan and sealed in place. A pressure differential through the brick was obtained by lowering the water level in the aspirator bottle. Pressure measurements were taken with an inclined draft gage. A constant-pressure differential was maintained by the valve in the outlet of the bottle. The time in seconds for one liter of air to flow through the brick at a constant-pressure differential was obtained.

Permeability data given in the table show that the value of K (permeability constant) and the rate of flow of air are not directly proportional to the pressure differential. The values of K for brand C at various pressures shed some light on the apparent discrepancies between the permeability values obtained and the generally accepted formula. Brand C is very impermeable and more nearly approaches a fire brick in resistance to air flow than any of the other brands included in this investigation The values for this material approximated a straight-line function between air-flow and pressure.

It is felt that a standardized form of equip-

TABLE IV

SUBSIDENCE OF INSULATING BRICK UNDER LOAD AT ELEVATED TEMPERATURES

Brand	Tests at 2300°F: Bulk density (lb./cu. ft.)	Load (lb./sq. in.)	Subsidence (%)	Tests at 2445°F: Bulk density (lb./cu. ft.)	Load (lb./sq. in.)	Subsidence (%)
A	39.6	7.92	2.57	38.5	77.0	15.35
B	45.4	9.08	11.68	46.9	9.38	24.07
C	41.2	8.24	3.51	41.8	8.36	7.02
D	No test					
E	47.2	9.44	10.70	47.8	9.56	22.45
F	45.5	9.10	24.40	49.5	9.90	26.50
G	57.5	11.50	0.92	56.8	11.36	8.78
H	40.8	8.16	0.66	37.2	7.44	3.66
I	56.0	11.20	Failed at 2300°			
J	28.6	5.72	Failed at 1945°			
K	51.5	10.30	0.00	54.2	10.84	3.07
	Test at 2600°F					
H	39.6	7.92	3.36			
K	53.3	10.66	7.18			

Load obtained: bulk density × 25/125

Example: Brand A $\frac{39.6 \text{ lb/cu. ft.} \times 25 \text{ lb./sq. in.}}{125 \text{ lb./cu. ft.}} = 7.92 \text{ lb /sq. in.}$

TABLE V

PERMEABILITY AND SPALLING RESISTANCE OF TEST BRICK

Brand	Permeability Constant at Differential Pressures of: 0.39	0.82	1.97 (cm. of water)	3.45	5.00	Spall Test Values Procedure: No. 1 Quenchings	No. 2 Transverse strength (lb./sq. in.)
A	0.326	0.265	0.181			5.0	21.9
B	0.214	0.184	0.136			10.0	55.9
C			0.013	0.0125	0.0122	37.0	39.7
D	0.133	0.116	0.089	0.077		7.5	(a)
E	0.471	0.375	0.243			20.0	16.3
F	0.422	0.335	0.234				16.7
G	0.273	0.235	0.171			13.0	(b)
H	0.530	0.404	0.262			4.0	(c)
I	0.611	0.454				2.0	(d)
J	0.231	0.198	0.169			7.5	(e)
K	0.291	0.246	0.173				16.5

(a) Broke after first air quench.
(b) " " second " "
(c) " " third " "
(d) " " " " "
(e) " " first " "

Permeability formula:

$$K = \frac{\text{volume of flow} \times \text{thickness}}{\text{area} \times \text{time of flow} \times \text{pressure differential}}$$

ment for the determination of the permeability of insulating brick is necessary to avoid errors in the classification of such materials. In order to be comparable it is absolutely essential that all permeability measurements be made under the same air conditions (temperature and relative humidity). Pressure should be measured near the face of the brick in order to avoid great error in obtaining absolute permeability values. No relation between permeability and per cent porosity is evident from the data obtained in this investigation.

Spalling resistance was determined according to two procedures. In the first, the $4^1/_2$- by $2^1/_2$-inch ends of the brick were heated in a furnace to 2000°F and then quenched in a blast of air. The testing cycle was approximately one hour. The values given in the table are for the number of quenchings required to produce 20% loss in weight in the test brick.

In the second method the entire brick was heated in a furnace to 2000°F and then quenched in a blast of air. After five alternate heating and quenching cycles of one hour each, the transverse strength of each brick was determined. The values given in the table are for an average of four specimens.

Brands B and C have exceptional values when tested according to both procedures. Brand B is a facing refractory insulation made of kaolin. Brand C is recommended as a back-up insulation and contains diatomaceous earth. The spalling resistance of the insulating brick in general was very poor.

III. Conclusions

The conclusions that can be drawn from this investigation are as follows:

(1) Better grades of "refractory" insulation have crushing strength values which, in proportion to their weight, approximate those of fire brick.

(2) The pyrometric cone equivalent of the facing "refractory" insulators is very good, being above cone 30 in practically every case.

(3) Considerable reheating shrinkage is obtained in most of the insulating brick, due to the fact that the manufacturer fires the brick to a temperature below that which he recommends for use and at which it is tested.

(4) Load deformation should be obtained by using a pressure proportional to the bulk density of the brick.

(5) Several of the brands showed excellent resistance to deformation under load at elevated temperatures. The performance of the remaining brands was mediocre.

(6) Spalling resistance of the insulating brick in general is low.

(7) Permeability of the insulating brick should be given serious consideration because of the considerable variation in this property for the various brands of brick tested.

(8) All comparative permeability tests should be made under the same conditions on a standardized permeability meter.

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MICROSCOPIC CONTROL OF PARTICLE SIZE IN REFRACTORY MANUFACTURE*

By W. L. Fabianic

Abstract

A comparison is made of the results of particle-size determinations by screening, elutriation, and microscopic count. Particular stress is laid on those sizes under 325-mesh (44 microns). The results obtained indicate that the microscope offers a quick practical method of sufficient accuracy to warrant its use in such work.

I. Introduction

The importance of correct grain size of raw materials entering into the manufacture of all refractory products has long been conceded and emphasized. Accurate control of particle size by mechanical sieving and wind separation is thoroughly understood by most refractory manufacturers.

Excluding the whiteware and electrical porcelain divisions of the ceramic field, the majority of the grain sizes of raw materials used is over 200-mesh. This is no longer true of the refractory field as it was formerly. Driven by the ever-increasing demand for higher quality refractories, the refractory manufacturer has been drifting more and more toward the use of finer grain sizes. At present some manufacturers are using a considerable bulk of material of 200-mesh and less.

Material between 200- and 325-mesh sometimes offers difficulty in screening, and under 325-mesh the control of grain size by screens fails and water elutriation is generally used. Water elutriation is objectionable because of its slowness.

In the present paper a comparison of grain size by screening, water elutriation, and microscopic examination is presented. No air elutriator[1] was available, so no comparison was obtained with this method.

II. Review of Literature

The most important work completed along analogous lines is that by Rieke and Mauve,[2] and the work of Harkort.[3] Rieke and Mauve determined the relation between grain size and elutriation velocity when using the Schöne apparatus. Harkort has described the Schulze apparatus and gives the relation between the elutriation velocity and grain size obtained with it.

III. Method of Comparison

Comparison was made of grain sizes on a nonplastic clay by (*a*) elutriation, (*b*) microscopic count, and (*c*) screening. The sizes considered were within the following limits:

Mesh	Micron size*
200–100	74–149
325–200	44–74
	25–44
	10–25
	00–10

* One micron = 0.00003937 in.

IV. Apparatus and Procedure

(A) Elutriation Apparatus

The elutriation apparatus consists of three copper cans 5, 7.2, and 14.6 centimeters in diameter, respectively, arranged in series so the overflow from the first can is passed through a funnel and tube into the bottom of the second, and similarly into the third. The overflow from the third can runs into the drain. In addition, a small Erlenmeyer flask, a set of balances, and a 100-mesh screen are needed to prepare the samples.

(1) Method of Operation The water flow was arranged so that the water level rose in the first can at a speed of 1.5 millimeters per second, in the second can at a speed of 0.7 millimeter per second, and in the third can at a speed of 0.18 millimeter per second. A 20-gram sample was weighed out and shaken up in a flask with 50 cubic centimeters of water. It was lawned through a 100-mesh sieve into the first and largest can. The residue on the screen was determined and subtracted from the total sample to secure the working sample. The water was started at the predetermined speed and allowed to run until the water in the third can ran clear.

The flow in the first and largest can carried over to the second can all particles under 0.04 millimeter in diameter. The flow in the second can

* Received January 16, 1934.

[1] *Bur. Stand. Tech. Paper*, No. 48 (1915).

[2] R. Rieke and L. Mauve, *Ber deut. keram. Ges.*, **8** [4], 209–24 (1927).

[3] H. Harkort, *ibid.*, **8** [1], 21 (1927).

carried over to the third can all particles under 0.025 millimeter, and the flow in the third can carried over into the drain all particles under 0.01 millimeter in diameter.

After settling overnight, most of the water in each can was siphoned off and the sediment washed into beakers, evaporated to dryness, and weighed. The percentage weight of the various sizes was then calculated.

(B) Microscopic Apparatus

The apparatus needed for this work consisted of a Bausch and Lomb microscope with a × 7.5 eyepiece and 16-millimeter objective, an eyepiece micrometer (Whipple disk), a stage micrometer, a small electric microscopic lamp, and two Sedgewick rafter counting cells with cover glasses.

(1) Method of Microscopic Count A representative sample of the material was taken and quartered down to about 50 grams and then screened through a 100-mesh screen. The screened material was further quartered down to about 5 grams. One gram was placed in a flask containing a half liter of filtered kerosene and agitated. (Water, alcohol, kerosene, or other liquids were used according to the solubility of the material being tested.)

Using a pipette, the counting cells were filled with the liquid, care being taken to remove all air bubbles, and the cover glasses were carefully adjusted.

After allowing to stand for 20 minutes, the cells were examined for uniformity and concentration. There should be from 75 to 150 particles in one field under observation. After a few trials, the proper dilution to give the required concentration of particles is easily ascertained.

The particles were then counted, and the percentage weights were calculated for each fraction from the microscopic data. The assumption was made that the particles were spherical and the average diameters were calculated using the formula[4]

$$D = \frac{\Sigma nd^3}{\Sigma nd^2}$$

where n = total number of particles of any given estimated diameter.

Using the specific gravity of the material and the formula

$$\frac{\pi d^3}{6}$$

[4] Theodore Hatch, *Jour. Franklin Inst.*, 215 [1], 27 (1933).

[5] $0.5236d^3 = \frac{\pi d^3}{6}$

the percentage weights of the various fractions were secured.

The micron sizes were as follows: 74–149, 44–74, 25–44, 10–25, 00–10.

Five different fields in each cell were counted (making ten fields) and the average percentage weight of each particle size was taken as the final result.

(C) Screening Apparatus

The apparatus used consisted of 100-mesh, 200 mesh, and 325-mesh Tyler standard screens.

(1) Method of Screening One hundred grams of material were weighed out and screened thoroughly. The percentages remaining on the 200-mesh, 325-mesh, and those passing the 325-mesh were calculated to percentage weights.

RESULTS

	Percentage	Micron size	Mesh size
Elutriation	15.4	44–149	+325–100
	13.6	25–44	Under 325
	16.0	10–25	Under 325
	55.0	00–10	
Microscopic count	5.2	74–149	+200–100
	7.1	44–74	+325–200
	11.4	25–44	Under 325
	18.3	10–25	Under 325
	58.0	00–10	
Screening	7.1	74–149	+200–100
	9.4	44–74	+325–200
	83.5	Under 44	Under 325

	Per cent between 325- and 100-mesh	Per cent total under 325-mesh	Per cent between 200- and 100-mesh	Per cent between 325- and 200-mesh
Elutriation	15.4	84.6		
Microscopic count	12.3	87.7	5.2	7.1
Screening	16.5	83.5	7.1	9.4

V. Conclusions

The results obtained show that a microscopic grain-size count is not very accurate, but they are satisfactory enough to warrant its consideration where a quick check on particle size is desired. The operator, after becoming familiar with the particular material he is checking, should soon be able to determine what the possible errors will be and how to minimize them.

It is realized that the present work is subjected to several sources of error, one of which is the assumption of sharply defined micron size limits for certain screens. It is assumed that a 325-mesh screen[6] permits particles of only 44 microns

[6] R. F. Geller, D. N. Evans, and A. S. Creamer, *Bur. Stand. Jour. Research*, 11 [3], 329 (1933); R. P. No. 594.

in diameter to pass, when in reality it has an allowable error of ±2.72 microns, and will also allow some irregular particles larger than this to pass. These oversize particles, however, were not present in any of the fractions in sufficient quantity to affect the results more than a few per cent of the total.

As a whole, the microscopic results obtained indicate strongly that for a quick practical method of grain-size control, the microscope again offers a possible solution, particularly to those places where elutriation by air or water is not convenient.

A capable operator can complete a determination of particle size in approximately three hours, while in some cases a brief examination of the material will determine how far along the grinding has proceeded. A microscopic analysis of particle size is not easy to perform, but neither is it beyond the ability of an intelligent petrographer.

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PARTICLE-SIZE DISTRIBUTION IN SOME GROUND CERAMIC RAW MATERIALS*

By Hermann F. Vieweg

Abstract

A study of the particle-size distribution in batch and continuous ground commercial flints and feldspars is discussed. A size-frequency law for batch-ground materials is proposed. The use of similar investigations in systematic modification of continuous grinding procedure is indicated.

I. Introduction

The size distribution of particles in ground flints and feldspars is of interest both theoretically and practically. From a theoretical viewpoint it is desirable to ascertain what variations in distribution are to be expected from changes in the grinding procedure and what types of distribution are characteristic of batch and continuous processes of pulverizing. From the practical standpoint this matter is of importance insofar as properties of ceramic ware may be influenced by the grain sizes of the ingredients and also because the dimensions of the particles of some substances may be a considerable factor in the silicosis problem.

The studies that have previously been made on ground ceramic raw materials have not been numerous. Martin,[1] making his measurements with the microscope, arrived at certain size-distribution relationships. Schramm and Scripture[2] obtained some excellent data on ground flints and feldspars, but they did not report anything on particle-size distribution. Andreasen,[3] in connection with a general study of the processes of grinding, included flint (cryptocrystalline) and feldspar, but he too failed to deduce a general distribution law.

A size-frequency relationship which is used to a considerable extent is that proposed by Mellor,[4] apparently purely hypothetically and without experimental basis.

II. Experimental

To learn what relations, if any, existed between grinding procedure and particle-size distribution, a group of typical commercial flints and feldspars was selected for study. Three batch-ground feldspars, two continuous-ground feldspars, two batch-ground flints, and three continuous-ground flints were subjected to careful analysis.

For grain diameters coarser than the opening of a 325-mesh sieve, determinations were made by means of screen analyses. For the finer portions, the Roller[5] air analyzer was used, with meas-

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* Presented at the Annual Meeting, American Ceramic Society, Pittsburgh, Pa., February, 1933 (White Wares Division). Received February 12, 1934.

[1] G. Martin, C. E. Blyth, and H. Tongue, "Researches on Theory of Fine Grinding," *Trans. Ceram. Soc.* [Eng.], 23, 61 (1924).

[2] E. Schramm and E. W. Scripture, Jr., "Particle-Size Distribution of Typical Feldspars and Flints," *Jour. Amer. Ceram. Soc.*, 10 [4], 264–67 (1927).

[3] A. H. M. Andreasen, *Kolloidchem. Beihefte*, 27, 23 (1928).

[4] J. W. Mellor, "Jackson's and Purdy's Surface Factors," *Trans. Ceram. Soc.* [Eng.], 9, 94 (1910).

[5] Roller, *Bur. Mines Tech. Paper*, No. 490 (1931).

urements of amounts finer than 5, 10, 20, and 40 microns, respectively. This apparatus was chosen because of the satisfactory results obtainable with it in the range from 5 microns up, when applied to materials of the type being investigated. The procedure followed and the methods of evaluating results were those discussed fully by Roller.[5]

III. Results

In tabulating the results obtained, it was considered advisable to state, for each of the particle diameters recorded, the cumulative per cent by weight corresponding to it. This cumulative per cent was calculated on the basis of the amount of the material finer than the size specified.

The results of this investigation are given in Tables I and II.

TABLE I

BATCH-GROUND MATERIALS

Feldspars

Grain diameters (μ)	2-hr. grinding	4-hr. grinding	6-hr. grinding
	(cumulative percentages by weight)		
5	10	15	24
10	12	30	41
20	30	46	58
40	50	66	79
44	53	70	82
74	65	83	94
105	75	93	100
149	86	100	
210	94		
300	100		

Flints

Grain diameters (μ)	140-mesh	200-mesh
	(cumulative percentages by weight)	
5	22	33
10	38	50
20	61	68
40	76	87
44	80	90
74	95	100
105	100	

TABLE II

CONTINUOUS GROUND MATERIALS

Feldspars

Grain diameter (μ)	140-mesh air-floated	200-mesh air-floated
	(cumulative percentages by weight)	
5	4	10
10	15	22
20	33	51
40	60	86
44	68	89
74	81	98
105	91	

Flints

Grain diameter (μ)	140-mesh air-floated	200-mesh air-floated	200-mesh
	(cumulative percentages by weight)		
5	9	15	11
10	20	26	29
20	40	46	57
40	71	77	87
44	76	81	90
74	94	100	100
105	100		

IV. Discussion

(1) Batch-Ground Materials In seeking to determine the functional relationship existing between particle diameter and cumulative per cent, various graphical methods were used. The most satisfactory procedure appears to be that shown in Fig. 1. The diagram brings out clearly that this relationship is semilogarithmically linear in the size ranges of particular interest in this investigation from 5 microns up. The only notable deviation is in the case of the finer portions of the 2-hour batch ground feldspar, in which it is quite probable that the grinding process may not have been sufficiently prolonged to remove effects resulting from the original state of subdivision of the material. On the other hand, it may be that this deviation from linearity is characteristic of the finest portions resulting from batch grinding. This question, as far as it pertains to sizes below 5 microns in commercial raw materials, was not contemplated in this investigation.

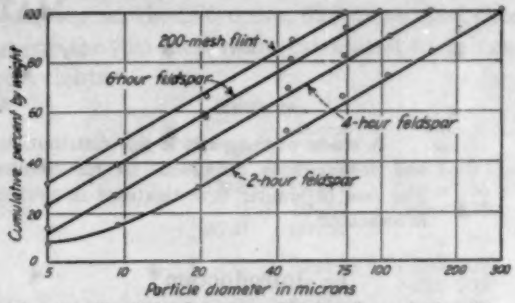

FIG. 1.—Particle size-mass distribution relationship in batch-ground materials.

On the basis of the data and the curves based thereon, one may deduce the following relation between the percentage of material, P, lying between two specified particle sizes, and the corresponding particle diameters, d_1 (smaller of the two), and d_2 (larger of the two):

$$P = k \frac{\log d_2}{\log d_1}$$

The constant, k, as will be shown later, is dependent on the nature of the material and of the batch-grinding process.

If this linear relation is correct, it follows that the frequency of occurrence of particles varies inversely as the fourth power of their diameters, or

$$f(d) = \frac{C}{d^4}$$

Here $f(d)$ is the function representing the particle-size frequency in terms of the particle diameter, d.

This is not in accord with the size distribution suggested by Mellor,[6] who assumed "that each fraction contains equal numbers of particles of all diameters between the extreme limits." According to his theory, $f(d) = C$. It should be remembered, however, that this formula was based entirely on assumption, and no experimental claims were made for it.

Martin[1] found that an exponential relation existed, and his results justified the following equation:

$$f(d) = ae^{-bd}$$

in which the parameters a and b varied slightly from one sample to another. It is questionable whether his extrapolation of results beyond the low limit of microscopic visibility was justified.

The data reported here, those obtained by Schramm and Scripture,[2] and by Andreasen[3] all had one fundamental point of difference from the results of Martin. In the first three cases, direct determinations were made of the amount of substances present in the material, *finer* than a certain size, the lowest fraction including everything down to the lowest particle size present. In the other case, microscopic measurements were made of the size-frequency down to the lowest size discernible with the microscope at the investigator's disposal and an extrapolation assumed to be justified. The methods employed by the first group are not subject to appreciable error resulting from overlooking or losing the finest portions.

Being thus confronted with three proposed size-frequency laws, calculations were made in order to determine to what degree experimental data might differentiate between them. The functions on which the calculations were based are as follows:

$$f(d) = \text{constant} \quad \text{(Mellor)} \qquad (1)$$
$$f(d) = ae^{-bd} \quad \text{(Martin)} \qquad (2)$$

in which a and b were taken as 300 and 0.16, values typical of his determinations.

$$f(d) = \frac{C}{d^4} \quad \text{(Vieweg)} \qquad (3)$$

Choosing as the basis for comparison the "6-hour batch-ground feldspar" and confining the calculations to the subscreen sizes, the following results are obtained:

[6] A. H. M. Andreasen, *loc. cit.*, p. 437.

DISTRIBUTION LAW

Grain diameters (μ)	Cumulative percentage by weight (1)	(2)	(3)	Found
5	0.014	1.1	24.0	24
10	0.22	5.5	42.5	41
20	3.5	27.5	60.0	58
40	68.3	73.3	78.4	79
44	82.0	82.0	82.0	82

Inspection of these results shows that there is a marked divergence between the mass distributions predicted by the three laws. Those proposed by Mellor and by Martin would require amounts in the finer fractions far below those encountered experimentally. On the other hand, the inverse fourth power law fits in very well with the observed data.

In order to ascertain whether or not the proposed distribution law was in agreement with the results obtained by other investigators on similar batch-ground materials, calculations of the same type were made with the data of Schramm and Scripture[2] and of Andreasen.[3] The first authors, making careful measurements by sedimentation methods, obtained the data included in the following table for a feldspar which had been batch-ground for 9 hours (10,000 revolutions), in the size range of particular interest here:

DISTRIBUTION LAW

Grain diameters (μ)	Cumulative percentage by weight, calculated by the author using formula (1)	(2)	(3)	Found (Schramm and Scripture)
3.4	0.002	0.5	28.6	28.6
5.0	0.011	1.3	38.1	42.2
10.2	0.18	8.1	55.3	52.8
20.6	3.04	33.5	72.2	71.6
28.6	16.2	60.8	81.6	81.6
44.0	90.7	90.7	90.7	90.7

Here again the data are found to be in good agreement with the law proposed as a result of this investigation, while those previously suggested differ markedly in the amount of fine material they call for.

A survey of the results of Andreasen's[6] researches shows that, although he made rather complete studies of a variety of ground materials, most of them are not comparable with the commercial products with which we are concerned here. However, in two cases, namely his experiments Nos. 26 and 27 which dealt with feldspar and flint (cryptocrystalline variety) ground in a ball mill for 140 and 220 minutes, respectively, with 45% water, the resultant materials were of the same character as those considered in this work.

Making the comparison between calculated and observed distribution on the basis of the

feldspar (there being no significant difference between the state of subdivision of the flint and that of the feldspar), the following results were obtained:

DISTRIBUTION LAW

Grain diameters (μ)	Cumulative percentage by weight, calculated by the author using formula (1)	(2)	(3)	Found (Andreasen)
3.97	0.0026	1.4	24.6	24.6
5.9	0.010	4.9	35.9	33.7
8.7	0.061	9.9	47.0	45.0
13.0	0.31	15.4	58.9	58.0
21.8	2.44	40.1	73.6	74.0
35.5	17.2	73.3	88.2	91.7
55.0	99.0	99.0	99.0	99.0

From these comparisons it follows that the results of other investigators are in reasonable agreement with the type of distribution suggested by this report as characteristic of batch-ground flints and feldspars.

From a practical point of view this means that it would be possible for a flint or feldspar grinder to get an accurate measure of the fineness of his product as the result of a single measurement, provided he had once established the value of the constant, k, as applied to the material being ground and the particular mechanism he was using. The value of this parameter, as calculated from the data obtained by the investigators whose results are considered here, ranges between 50 and 75. It should be noted that the general nature of the size distribution is not altered by variations of the value of k; it is merely a measure of the range of sizes covered by the sample.

These results are also of interest insofar as they are involved in the calculation of the "mean diameter" of a size group. The formulation proposed by Mellor,[4] which is the volume-mean diameter based on the assumption of equal frequency of all particle sizes within the limits under consideration, is still used to some extent. In the range from a particle diameter, d, to an upper particle diameter, cd (c being the ratio of the largest size to the smallest), the mean diameter is expressed as

$$d_m = d^3 \sqrt{\frac{(c^2+1)(c+1)}{4}}$$

On the basis of the inverse fourth-power distribution function, the following mean diameters[7] would result:

[7] See G. St. J. Perrott and S. P. Kinney, "Meaning and Microscopic Measurement of Average Particle Size," *Jour. Amer. Ceram. Soc.*, 6 [2], 426 (1923).

$$\text{Volume basis, } d_m = d\,\frac{(c-1)}{\log c}$$

$$\text{Surface basis, } d_m = d\,\frac{c \log c}{(c-1)}$$

$$\text{Linear basis, } d_m = d\,\frac{2c}{(c+1)}$$

$$\text{Numerical basis, } d_m = d\,\frac{3/2\, c\,(c^2-1)}{(c^3-1)}$$

A simple calculation will suffice to show how the volume-mean diameter would compare with that proposed by Mellor. Assuming a size fraction ranging from 10 to 20 microns in diameter, using Mellor's formula an average of 15.5 microns would be found. On the other hand, the expression above gives a value of 14.4 microns. It should be noted that in calculating surface factors the surface-mean diameter is really the correct quantity to determine, which would be 13.8 in this case.

(2) Continuous-Ground Materials As might have been predicted in the case of continuous-ground materials, no simple relation appears for the mass distribution. Figure 2 represents the size-mass relationship for two of the materials which are

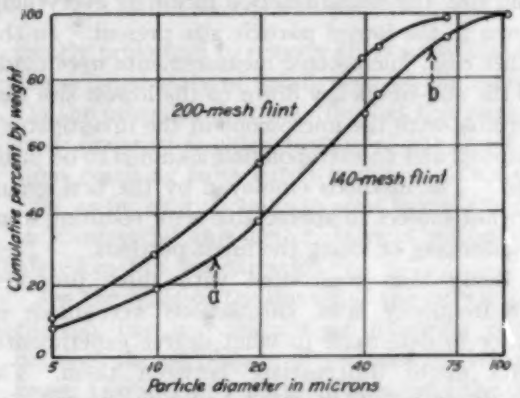

FIG. 2.—Particle size-mass distribution relationship in continuous-ground materials.

typical of the group studied. The general appearance of a representative curve is such as one might expect if one of the batch-ground materials were mixed with a considerable amount of another specimen consisting entirely of a size fraction ranging between fairly narrow limits. This is the type of distribution one might hope to achieve with a continuous grinding operation. Thus the portion of the lower curve between points a and b would correspond to the effect of adding an intermediately sized mass of substance

to a material having an otherwise linear distribution, as was observed in the batch-ground samples.

A numerical illustration may be of interest. Let it be assumed that equal amounts of the "140-mesh" batch-ground flint and that portion of it lying in the range 15 to 70 microns be mixed together. The calculated composition of this mixture is then to be compared with the experimentally determined composition of the "140-mesh air-floated" flint. The results are tabulated below.

Diameters (μ)	Cumulative percentages by weight			
	A	*B*	*C*	*D*
5	22		11	9
10	38		19	20
15	...	0		
20	61	18.4	39.7	40
40	76	65.0	70.5	71
44	80	71.7	75.8	76
70		100.0		
74	95		97.5	94
105	100		100.0	100

A = 140-mesh batch-ground flint.
B = 15- to 70-micron portion of 140-mesh flint, *A*.
C = calculated composition of 50–50 mixture of *A* and *B*.
D = determined composition of 140-mesh air-floated flint.

This is in agreement with the statement that the size distribution of the continuous ground material is similar to that of a batch-ground product to which an intermediate fraction has been added. The limits of this intermediate portion coincide with the points of inflection, *a* and *b*, marked on the lower curve of Fig. 2.

From the point of view of possible modifications in the grinding procedure to obtain different size-distributions, an analysis of such a curve may be of importance. The size range indicated by the horizontal distance, *a*–*b*, gives some measure of how well the process succeeds in producing an excess of material in a limited size range. The shorter the interval *a* to *b*, the more uniform will be the major portion of the product. The vertical distance, *a*–*b*, measures the magnitude of this portion.

A study of a series of curves of this type, correlated with changes in the mechanical features of the continuous-grinding mechanism, should make it possible to so modify grinding practice as to produce the optimum size-distribution desired in the particular substance. For example, if it were desired to produce a maximum amount of one particular size, the ideal objective would be a curve consisting of a straight line running vertically through the abscissa designating the size in question.

V. Summary

(1) Commercial batch-ground flints and feldspars are found to have particle-size distributions in the range above 5 microns, characterized by an inverse fourth power size-frequency.

(2) Commercial continuous ground flints and feldspars are found to have more complex particle-size distributions, which are related to those of the batch-ground materials.

Acknowledgment The writer wishes to express his appreciation to G. H. Brown for his interest and coöperation in this investigation.

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EFFECT OF VARIATIONS IN THE ALUMINA-SILICA RATIO IN FUSED REFRACTORY MATERIALS UPON RESISTANCE TO METAL OXIDES*

By Charles McMullen, A. A. Turner, and G. J. Easter

Abstract

Solid pieces of electrically fused material, varying in composition from 63% alumina 37% silica to 100% alumina, of the ordinary abrasive grade were heated in contact with cast iron and brass which were allowed to oxidize and attack the refractory. The least attack was found in the case of the iron with 80% alumina 20% silica, and in the case of the brass with straight alumina, although the 80% alumina 20% silica was not greatly inferior.

Bonds were developed for the materials thus selected and confirmatory tests were made on crucible fusions. Arc and powdered-coal furnaces lined with the bonded materials have proved successful.

I. Introduction

Within the past few years the increased demand for special and high tensile cast iron has focused the attention of the foundry industry on the new types of melting furnaces, such as the rocking type of electric arc furnace and the powdered-coal fired rotary furnace, owing to the difficulty of producing regularly high-quality irons with usual cupola practice.

The problem of refractory linings for these new furnaces is exceedingly difficult since the slag action and deterioration due to heat are increased with the higher temperature present. This is of concern not only to the foundryman but to the furnace manufacturer whose sales may be limited by refractory troubles.

The entire range of natural clays, not only the usual types of fire clays but the kaolin and diaspore clays and materials of the sillimanite and andalusite group, having a theoretical composition of $Al_2O_3 \cdot SiO_2$, have been tried with more or less encouraging, but by no means universally satisfactory, results.

Some manufacturers have attempted to solve their refractory problems by the use of uninsulated linings. The advantage in this case is that the refractory is kept below its melting point by the rapid heat transfer through the lining. This method, however, is not the most economical because of higher fuel costs. Others, by insulating the lining, have lower fuel costs but obtain shorter life from the refractories.

While the problems met with in the melting of nonferrous metals in these furnaces have not been as acute as in ferrous production, nevertheless there is undoubtedly much work still to be done in the nonferrous field to achieve the ultimate in economy in refractory costs. Consequently an investigation of refractory materials for nonferrous melting was conducted simultaneously with the work on materials for use in the production of iron.

Silicon-carbide refractories, both as prefired and as ramming materials, are being regularly and successfully used for certain of these furnaces. There is, in particular, a widespread and growing use of silicon-carbide refractory shapes for door-frame linings including sill blocks in the rocking type of electric-arc furnaces. Due to their high strength at elevated temperatures and their excellent resistance to thermal shock, these shapes keep this vital section of the lining in satisfactory condition and protect the rest of the refractory material. Silicon-carbide linings, however, have high thermal and electrical conductivities and are not inert to all types of metals and slags so that their use is subject to certain limitations.

The present work has been confined primarily to electrically fused materials in the silica-alumina field since these seemed to offer the greatest possibility of success due to their refractoriness, thermal stability, and satisfactory chemical properties. From a chemical standpoint, electrically fused magnesia and magnesia-alumina spinels offer an interesting field for investigation. However, the difficulty of bonding this group of refractories properly, their spalling tendencies, and their volume changes in service present such formidable obstacles that the study of the silica-alumina field was preferred.

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II. Tests on Solid Fused Masses

In the development of bonded refractories and rammed monolithic linings to be matured in place, a study was first made of the relative attack of the metals and their oxides on the fused material itself in order to separate this phase of the problem from that involved in the selection of a proper bond. This was followed by similar tests on bonded fused material.

Fusions were made in an electric arc of alumina of the grade ordinarily used for abrasives and mixtures of silica with 63, 72, and 80% of such alumina.

Microscopic examination of the fusions themselves showed the following materials to be present:

63% Al_2O_3	37% SiO_2	Mullite with considerable glass; practically no corundum
72% Al_2O_3	28% SiO_2	Largely mullite; little corundum; some glass
80% Al_2O_3	20% SiO_2	Largely mullite; some corundum; little glass
100% Al_2O_3		Very largely α-corundum

Large lumps of these materials were selected and lapped smooth on one side using silicon-carbide grain on a lapping wheel. Equal weights of gray cast iron in lump form were placed on one series of pieces and samples of red brass (approximately 85 Cu, 5 Pb, 5 Zn, and 5% Sn) were placed on a similar series.

After being heated to 1350°C for 24 hours, during which time the metals oxidized almost completely, the refractory pieces of each group were broken through the attacked section and examined microscopically.

The various specimens tested with the cast iron showed distinctive characteristics. The iron oxide apparently reacted readily with the siliceous intercrystalline glass which was present in those pieces high in silica. In the 100% alumina specimen it was absorbed by the corundum crystals and also penetrated deeply along the intercrystalline boundaries. With the mullite crystals themselves it showed little or no reaction of any sort. The refractory composed of 80% alumina and 20% silica appeared definitely the least affected of the lot. In this piece the iron oxide penetrated the surface smoothly and evenly to a depth of less than $^1/_{64}$ inch but showed no tendency to disrupt it.

In comparing the structure of the 80% alumina fusion with those of a lower alumina content, a striking difference was observable. While the mullite crystals in the 80% alumina fusion had the typical needle-like structure, they were interlocked with the corundum crystals and were noticeably shorter than those present in the fusions of a lower alumina content. The corundum crystals apparently offered considerably more opposition to the mullite crystal growth than the glass present in the other fusions. The resulting structure of the 80% alumina fusion was quite compact whereas the structure of the other fusions was splintery. It was felt that this structural difference was responsible even more than the chemical difference for the increased resistance to the iron-oxide attack with the 80% alumina material. It is interesting to note this apparent contradiction since our tests showed the mullite crystals to have the greatest resistance to the iron oxide, and more mullite was apparently developed in the 72% alumina fusion than in the 80% alumina material.

This striking difference in structure is clearly shown in the photomicrographs of thin sections of these fusions. Figure 1 (1) is a thin section of the 80% alumina fusion. The penetration is comparatively slight (approximately 0.013 inch) and the mullite crystals and original structure are still present. Figure 1 (2), a thin section of the 72% alumina fusion, clearly shows the coarser crystal growth, the deeper penetration, and the undermining of the structure enabling the slag to wash away the crystals. In (1) the upper line is approximately the original surface of the fusion, while in (2) considerable material has already been washed away. Penetration has taken place between the crystals to a depth several times that observable in the 80% alumina specimen, and the corundum crystals themselves show marked absorption of or reaction with the iron oxide. In (3) a thin section through the 100% alumina fusion is given.

In the brass tests, the attack was considerably more violent due to the greater fluidity of the oxide. The effect was apparently chiefly that of the copper oxide which again particularly attacked the glass which was present, as is evident in (4) which shows the destruction wrought by the bodily tearing away of the mullite crystals in the 72% alumina melt. The mullite crystals themselves seem relatively unaffected. On the other hand, the corundum in the 100% alumina melt (5) again shows absorption of the oxide accompanied by more severe erosion than in the

case of the iron. The 80% alumina piece (6) seemed inferior to the 100% specimen in this case, particularly in that the oxide penetration was much deeper.

III. Work on Bonded Materials

The experiments up to this point indicated the use of the 80% alumina 20% silica for iron furnaces and the use of the straight alumina material for brass. Before attempting to apply these materials as furnace linings, however, it was necessary to develop suitable bonds for them. For rammed monolithic linings, it was necessary to produce a ramming compound with a bond which would have some strength on air-drying and one which would show a gradual maturing over a wide temperature range. While the face of a rammed-in monolithic lining in either an electric furnace or a powdered-coal furnace may reach temperatures in excess of 1650°C, the temperature through the lining falls off sharply. The selection of too refractory a bond which could only be matured on the surface would thus give very unsatisfactory results in service. One of the advantages which a monolithic lining has over a prefired refractory is that in the latter, whatever cracks may occur in service usually extend through the entire thickness of the prefired piece, whereas with a monolithic lining in which only a part of the material has set up, a crack will go only through the vitrified inner layer and any metal penetration will be stopped by the unvitrified cushion of cement. It is necessary, however, for this vitrified layer to be of substantial thickness so as to withstand mechanical wear and keep the remainder of the cement in place.

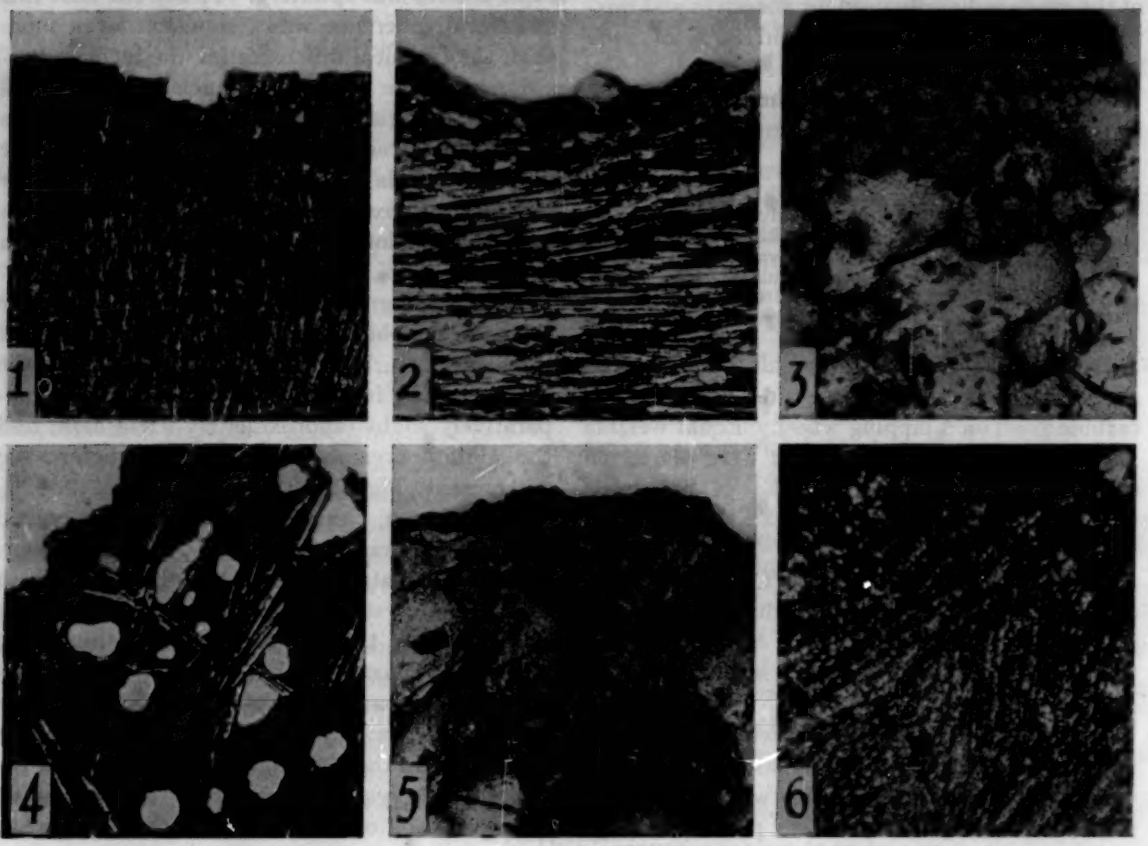

FIG. 1.—Section of fused lump, ×35: (1) 80% Al_2O_3, 20% SiO_2 cast-iron test; (2) 72% Al_2O_3, 28% SiO_2 cast-iron test; (3) 100% Al_2O_3 cast-iron test; (4) 72% Al_2O_3, 28% SiO_2 brass test; (5) 100% Al_2O_3 brass test; (6) 80% Al_2O_3, 20% SiO_2 brass test.

After numerous trials, bonds were secured for the ramming materials which met the foregoing requirements and gave satisfactory strengths in the finished product at the temperatures en-

countered in practice. They also had negligible firing and drying shrinkages and yielded a product of somewhat closer structure after firing than is met with in other materials which have been used for these applications. At the same time, bonds were developed for prefired shapes which gave approximately the same desirable results as were obtained with the monolithic-lining materials.

A series of crucibles were then made from the various fusions after the materials had been crushed and screened into four fractions which were recombined to give the maximum density to the resultant mixture of grits. The crucibles were fired at approximately 1450°C and then loaded with gray cast iron and with the same red brass as was used on the tests on the fused materials. The crucibles containing the gray cast iron were held for 15 hours at 1350°C and in those containing the red brass, the metal was covered with a layer of charcoal and held at 1350°C for 15 hours.

After the test the crucibles were broken up and the fragments were carefully examined under the microscope. The results very generally confirmed the preceding tests. Practically no attack could be observed on the grains used in the crucibles made of the substances previously indicated for use in the respective cases. The bonds used were penetrated, but the attack was comparatively slight.

IV. Results in Operating Furnaces

A number of tests on monolithic installations of these materials have been made in actual service with satisfactory results. At one of the plants in the Detroit district where there are four 750- to 1000-pound rocking-type direct-arc furnaces producing a variety of red brasses, a rammed monolithic lining with the 100% fused alumina material gave approximately 60% longer life than a previously used monolithic lining, and approximately three times the life of the regular prefired block lining which was regularly in use. During the entire run, the sill was patched and repaired several times, but the remainder of the lining was not patched or washed in any way. On relining this furnace the end walls were left in position as the total amount of wear in the two end walls measured less than one-half inch. A second lining using a silicon-carbide sill block as well as silicon-carbide jambs and lintel has now been in service for some months with the lining still in perfect condition. No patching or washing has been necessary with this furnace to date.

Similar satisfactory results have been obtained on linings for ferrous melting using the higher silica "mullite" composition, although the exact number of heats in comparison with previous runs is not at present available.

The largest furnace lined with these materials so far has been a powdered coal-fired rotary melting furnace in the Chicago district. This furnace is 6 feet inside diameter and 13 feet long. A 6-inch layer of the 80% alumina electric furnace mullite ramming cement was used, backed up with a 6-inch layer of fire brick.

The lining was carefully dried out and sintered in place using only the powdered-coal burner, with no circumferential cracks in the barrel of the furnace and with only one longitudinal crack apparent. No expansion joints were used either longitudinally or circumferentially. This would indicate that unusually large furnaces can be lined with these monolithic lining materials without serious cracking.

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Sunday	(1)	Registration
	(2)	Committee Meetings
	(3)	President's Reception
	(4)	Concert
Monday	A.M.	Symposium on Ceramic Ware Firing
	P.M.	(1) Ceramic Art and Design
		(2) Committee Reports
	Evening	Buffalo Shuffle—an informal blowout
Tuesday	A.M.	Division Meetings
	P.M.	Division Meetings
	Evening	Edward Orton, Jr., Fellow Lecture by Dr. Ries, Cornell University, Ithaca, N. Y.
Wednesday	A.M.	Division Meetings
	P.M.	Division Meetings
	Evening	(1) Students' Reception and Dinner
		(2) Dance and Entertainment
Thursday	A.M.	(1) Refractories Division Meeting
		(2) Buffalo Plant Trips
	P.M.	To Niagara Falls
	Evening	Dinner at the Falls, Scenic Ride
Friday	All Day	Trips to
		(1) Corning, Rochester, and Erie
		(2) Shaleville and Jewettville

CERAMIC ABSTRACTS[1]

Compiled by the

AMERICAN CERAMIC SOCIETY

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Vol. 14 **January, 1935** **No. 1**

Abrasives

Abrasives. Anon. *Rev. gén. mat. plastiques*, **10**, 68–69 (1934); abstracted in *Chem. Zentr.*, **i**, 3904 (1934).—A short review of the manufacture and use of abrasives, especially Alundum and silicon carbide abrasives, is given. M.V.K.

Abrasives for polishing and buffing. A. H. Anderson. *Metal Cleaning & Finishing*, **6** [9], 483 (1934).—A. discusses progress made in abrasive manufacture from the days when no production control was exercised. Specifications have been increased and tightened to a point commercially impracticable a few years ago. E.J.V.

Grinding cemented tungsten- and tantalum carbide-tipped tools economically. J. M. Highducheck. *Trans. A.S.M.E.*, **55**, RP-2 (1933); abstracted in *Mech. Eng.*, **56** [2], 116 (1934). F.G.H.

PATENTS

Abrading wheels. R. E. L. Warburton and L. Molloy. Brit. 416,076, Sept. 19, 1934.

Abrasive article. H. C. Martin (Carborundum Co.). U. S. 19,318, Sept. 18, 1934 (reissue).

Abrasive coated materials. W. J. Tennant (Behr-Manning Corp.). Brit. 398,907, Oct. 4, 1933.

Actuating mechanism for profile grinders. C. L. Ross. U. S. 1,973,507, Sept. 11, 1934.

Apparatus for applying abrasive granules, with the aid of an electric field, to a support coated with adhesive. Behr-Manning Corp. Ger. 598,354, June 13, 1934. (*C.A.*)

Boron carbide and method of making. W. W. Triggs (Norton Co.). Brit. 415,392, Sept. 5, 1934.

Burnishing or polishing device. J. F. Fabregat. U. S. 1,974,771, Sept. 25, 1934.

Centerless grinding machines. Churchill Machine Tool Co., Ltd., and H. Longthorpe. Brit. 416,271, Sept. 19, 1934.

Cylinder grinder. M. C. Hutto (Hutto Engineering Co., Inc.). U. S. 1,972,890, Sept. 11, 1934.

Device for dressing profiled grinding disks, in particular disks for grinding screw threads. H. Lindner. Brit. 416,336, Sept. 26, 1934.

Devices for grinding rollers with a convex longitudinal curvature on circular grinding machines. A. Pfungst-Stiftung. Brit. 415,642, Sept. 5, 1934.

Gear-lapping machines. A. H. Stevens (Michigan Tool Co.). Brit. 415,583, Sept. 5, 1934.

Grinding machine. R. E. W. Harrison and K. T. Schledorn (Heald Machine Co.). U. S. 1,973,626, Sept. 11, 1934. B. E. Rockhoff (Detroit Steel Products Co.). U. S. 1,973,177, Sept. 11, 1934. O. A. Swanson. U. S 1,974,696, Sept. 25, 1934. G. Wagner. Brit. 416,204 Sept. 19, 1934.

Hone or abrading tool. W. R. Cooper. U. S. 1,975,193, Oct. 2, 1934.

Internal grinding machine. Churchill Machine Tool Co., Ltd., and H. H. Asbridge. Brit. 415,879, Sept. 12, 1934.

Method of balancing abrasive wheels and wheels thereby balanced. H. R. Simonds (Simonds Worden White Co.). U. S. 1,975,053, Sept. 25, 1934.

Method of grinding. C. H. Schmalz. U. S. 1,973,511, Sept. 11, 1934.

Method and machine for grinding, lapping, polishing, or honing safety-razor blades or strips for forming such blades. J. Booth. Brit. 416,411, Sept. 26, 1934.

Process of and machine for lapping work pieces of circular cross-section. Cincinnati Grinders, Inc. Brit. 416,165, Sept. 19, 1934.

Profile grinder. C. L. Ross. U. S. 1,973,508, Sept. 11, 1934.

Reinforced abrasive wheel and its manufacture. R. C. Benner and W. G. Soley (Carborundum Co.). U. S. 1,975,070, Oct. 2, 1934.

Surface-grinding machines. Luke & Spencer, Ltd., and H. Critchley. Brit. 415,452, Sept. 5, 1934.

Tap grinding machine. E. C. Oliver. U. S. 1,974,365, Sept. 18, 1934.

Valve seat grinding tool. Black & Decker Mfg. Co. Brit. 415,951, Sept. 12, 1934.

[1] The bold-face number following the journal is the volume, the issue number is in brackets, followed by the page numbers, then the year in parentheses.

Art and Archeology

Artistic and flow glazes for pottery. A. Z. *Keram. Rund.*, **42** [13], 160–62; [14], 174–75 (1934).—Directions are given for the calculation and production of bright colored, mat, crystal, flow, flow over, and lustrous glazes, and enamels. Compositions are analyzed. M.V.K.

Borden's find green glass jar preferred for use in kitchen. ANON. *Amer. Glass Rev.*, **53** [45], 8 (1934).—Green glassware was found to be the favorite colored ware for the kitchen. It also provides a vessel for protecting food from sunlight. M.C.S.

Comparison of sources of light of different colors. HANS KOENIG. *Helv. Phys. Acta*, **7** [4], 433–53 (1934); abstracted in *Physik. Ber.*, **15** [16], 1332 (1934).—Photometric methods for comparing light of different colors are discussed; it is concluded that only an objective method will be internationally accepted as standard, and that selenium cells with filter arrangement can be used for such a method. Experiences with Se cells are described. M.H.

Cone 10 raw crystal glaze. H. THIEMECKE. *Jour. Amer. Ceram. Soc.*, **17** [11], 359–62 (1934).

Decorated glass. E. M. HOMMEL. *Glass Ind.*, **15** [9], 215–16 (1934).—The majority of glassware is ornamented with transparent or opaque vitrifiable colors fired on the surface of the glass. The various methods of application are described in detail. E.J.V.

Van Frytom tile. ANON. *Illus. London News*, **185**, 21 (1934).—Six photos of Delft tile painted by Frederick van Frytom (d. 1658) are shown. H.H.S.

Glass art of Württemberg. WERNER BUDDEMANN. *Sprechsaal*, **67** [32], 477–79 (1934).—B. reviews present trends in the manufacture of artistic glassware. Illustrated. M.V.K.

Photoelectric color matcher. R. F. BISBEE. *Enamelist*, **11** [11], 9–10 (1934).—In the Westinghouse color matcher colored light is sent to a sample, and the amount diffusely reflected is sent to a phototube which controls an amplifying tube and an indicating microammeter. Three color filters provide red, green, and blue light. The voltage regulator eliminates the variability of illumination. The color match readings are relative, being in all cases referred to a standard which can be one of the samples. In this apparatus the direct (glare) reflection never gets to the phototube, and the readings take no account of the gloss. A general discussion of color matching and the use of the instrument for actual matching are taken up. E.J.V.

Pottery colors. E. W. T. MAYER. Presented at meeting of Pottery Section, Ceramic Society [England], Stoke-on-Trent, Sept., 1934; *Pottery Gaz.*, **59** [688], 1219–23 (1934). E.J.V.

Roumanian civilization of 2500 B.C. D. V. ROSETTI. *Illus. London News*, **184**, 1028–29 (1934).—Discoveries at the prehistoric site of Vidra near Bucharest are of great importance in the prehistory of south-eastern Europe. Illustrated. H.H.S.

Six thousand years of pottery art. J. GRELL. *Tonind.-Ztg.*, **58** [55], 659–62 (1934); *Keram. Rund.*, **42** [27], 329–32 (1934).—The exhibition at the Berlin State Museum of pottery showing the development of ceramic art is discussed. Illustrated. M.V.K.

Supposed fossil ear of maize from Cuzco, Peru. ROLAND W. BROWN. *Jour. Wash. Acad. Sci.*, **24**, 293–96 (1934).—Sectioning and examination of the alleged fossil ear of maize described in 1919 by Knowlton shows that it is a cleverly handmade, low-fired, clay copy of an ear of Peruvian maize. J.B.A.

BOOKS

Dictionary of Color Standards. ANON. Published by British Color Council. Reviewed in *Amer. Glass Rev.*, **53** [47], 21 (1934).—Two hundred twenty colors are presented on pure silk ribbon, each with a name, number, and code number. M.C.S.

Old Dutch Tile. Vol. II. E. M. VIS AND C. DE GEUS. Text by F. W. HUDIG. 97 pp., 62 plates, 46 colored. Karl W. Hiersemann, Leipzig, 1934. Price 80 Rm. Reviewed in *Times Lit. Supp.*, **33**, 461 (1934). H.H.S.

PATENTS

Decalcomania and method of making. E. A. BORDEN. U. S. 1,973,403, Sept. 11, 1934.

Designs for:

Bottle. A. L. KEY (American Spirits, Inc.). U. S. 93,480, Oct. 2, 1934. L. J. KIHN (J. T. & A. Hamilton Co.). U. S. 93,481, Oct. 2, 1934. F. V. KLOTZ (Pinaud, Inc.). U. S. 93,483, Oct. 2, 1934. H. R. MCDONALD (Hart Glass Mfg. Co.). U. S. 93,351, Sept. 18, 1934. RALPH NOTTEBAUM. U. S. 93,256, Sept. 18, 1934. OTTO SEIDNER (Otto Seidner, Inc.). U. S. 93,524, Oct. 2, 1934. FRASIER SMITH (Hazel-Atlas Glass Co.). U. S. 93,526, Oct. 2, 1934. J. S. STEELMAN (Whitall Tatum Co.). U. S. 93,297 to 93,304, Sept. 18, 1934.

Glass flask. UMBERTO BERTOCCHINI. U. S. 93,326, Sept. 18, 1934.

Goblet. E. M. BOTTOME (Fostoria Glass Co.). U. S. 93,380, Sept. 25, 1934.

Plate. F. J. CUTHBERTSON. U. S. 93,459, Oct. 2, 1934. LUDWIG FROELICH (Heinrich & Winterling, Inc.). U. S. 93,467, Oct. 2, 1934.

Range. RUDOLPH HOFFMAN (American Stove Co.). U. S. 93,397, Sept. 25, 1934.

Serving dish. M. W. REH. U. S. 93,520, Oct. 2, 1934.

Shelf-back lavatory. R. E. CRANE. U. S. 93,329, Sept. 18, 1934.

Tumbler. J. E. SPENCE (Hazel-Atlas Glass Co.). U. S. 93,296, Sept. 18, 1934.

Jets for sandblast apparatus. GEWERKSCHAFT WALLRAUM. Ger. 593,057, Feb. 1, 1934. The jet consists of a hard metal liner completely housed in iron covering and affixed thereto by hard solder to reduce the risk of fracture and to hold any pieces of the hard metal in place in the event of fracture occurring. (*J.S.G.T.*)

Cements

Effects of fluorides on the thermal synthesis of calcium silicate. II. SHOICHIRO NAGAI AND MAKIZO MIYASAKA. *Jour. Soc. Chem. Ind.* [Japan], **37** [8], 419–21*B* (1934).—The results are tabulated. For previous reports see *Ceram. Abs.*, **11** [5], 291 (1932); **12** [10–11], 354 (1933). M.V.K.

Expansion of cement due to MgO. K. BALTHAZAR. *Tonind.-Ztg.*, **58** [16], 194–95 (1934); abstracted in *Chim. & ind.*, **32** [1], 121–22 (1934).—The expansion of Portland cement rich in MgO depends on the quantity of ferric oxide contained in it. This quantity must correspond to the formula, $Fe_2O_3 = 2(2 + 0.1MgO)$. M.V.K.

Fluated acid-stable materials. P. N. GRIGORIEV. *Ogneuporui*, **1** [5], 33–36 (1933); abstracted in *Chem. Zentr.*, **i**, 2104 (1934).—From the composition of Höchster's cements consisting of sand, Na_2SiF_6, crystalline Si, and water, G. concludes that their course of reaction during setting proceeds the same as in Kessler's fluates. The final products of the reaction important for acid stability are NaF and H_2SiO_3. Sand is merely a filler and the crystalline Si produces a small expansion because of the H_2-evolution. Acid-stable cements for various purposes can therefore be produced on the basis of Na_2SiF_6 and Na_2SiO_3 and when using corresponding fillers. M.V.K.

Fused cement. I. Rôle of iron oxide in aluminous cement. KEI-ICHI AKIYAMA. *Jour. Soc. Chem. Ind.* [Japan], **37** [7], 382–85*B* (1934).—The results are shown in tables. M.V.K.

Gypsum—from mine to market. L. V. ROBINSON. *Can. Mining Met. Bull.*, No. 270, pp. 482–87 (1934).—Mining, crushing, and calcining methods are briefly described. Qualities of some gypsum products are outlined. G.M.H.

Industrial utilization of waste products in the manufacture of alumina from kaolin. P. P. BUDNIKOFF. *Chem.-Ztg.*, **57** [101], 1000–1001 (1933).—The by-products from the production of alumina from kaolin by the soda-lime method may be used as an independent binding agent or as an artificial addition in the manufacture of anhydrite and anhydrite dolomite cements. These by-products can also be admixed to Portland cement. M.V.K.

Synthesis of calcium silicates. VIII. SHOICHIRO NAGAI AND GENTARO SAWAYAMA. *Jour. Soc. Chem. Ind.* [Japan], **37** [7], 380–82*B* (1934).—Further studies of the thermal synthesis of calcium silicates in the presence of small amounts of alumina and on the hydraulic strength of the resulting products are discussed. The results are tabulated. For Part VII see *Ceram. Abs.*, **12** [12], 413 (1933). M.V.K.

Thermal characteristics of cement. EDMOND MARCOTTE. *Chim. & ind.*, **31** [6], 1291–1300 (1934).—Thermal characteristics permitting not only the observation of the phenomena of setting and hardening but also the differentiating of various hydraulic binders and the forecasting of the future mechanical resistance of cement are discussed. M.V.K.

PATENTS

Cement. F. D. SNELL. U. S. 1,973,732, Sept. 18, 1934. A cement composition capable of setting to an acid-proof and water-proof product comprises a dry mixture of ground aggregate, a readily soluble powdered sodium silicate, and sodium fluosilicate in a proportion which completely neutralizes the sodium oxide of the silicate, the silicate mixture being completely soluble in water and capable of being applied before setting commences.

Keene's cement. W. C. HANSEN (American Cyanamid Co.). U. S. 1,972,888, Sept. 11, 1934.

Plaster of Paris. SUSUMU TANAKA. Japan. 101, 237, May 22, 1933. By calcining a mixture of gypsum, $Al(OH)_3$, Na_2SO_4, and fluorspar at about 1000° for 3 hr. and then powdering, there is formed a plaster that when mixed with about 10% H_2O sets to a very hard mass. (*C.A.*)

Enamels

Adherence of sheet iron enamel. A. DIETZEL. *Glashütte*, **64** [33], 546–48 (1934).—Recent researches dealing with (1) the expansion behavior of enamel, (2) adherence of enamel containing adhering oxides, and (3) reactions promoting adherence are reviewed. On the basis of these studies, D. concludes that good, *i.e.*, technically usable, adhering materials for sheet iron are compounds of such metals which are more noble than iron. References are given. M.V.K.

Alumina in enamel. RICHARD ALDINGER. *Keram. Rund.*, **42** [20], 244–46 (1934).—Alumina does not opacify the enamel but it increases the opacifying effect of other materials and the coefficient of expansion. Alumina does not affect any properties of the enamel. Clay is the best and cheapest addition to the mill. M.V.K.

Antimony poisoning from enameled vessels. ANON. *Ministry of Health Memo.*, 171/Med., 3 pp. H. M. Stationery Office, London, 1933. Abstracted in *U. S. Pub. Health Eng. Abs.*, **13** [Mi], 18 (1933); *Bull. Hyg.*, **8** [6], 445 (1933).—Antimony oxide is widely used as an opacifying agent in enameling hardware on account of its comparative cheapness. In low-grade enamel the enamel matrix enclosing the oxide particles is not an adequate protection. These enamels are made from a mixture relatively low in silica content and are fired at a comparatively low temperature. They are not acid-proof and appear to be readily dissolved by citric, tartaric, acetic, and other acids present in food thus exposing the antimony oxides which are dissolved. If such vessels are used for acid drinks, such as lemonade, toxic amounts are dissolved. Three outbreaks so caused are reported. The first, in 1928 at Newcastle-upon-Tyne, resulted in 70 cases of tartar emetic poisoning, the solvent being lemonade made from "lemonade" crystals. The second at Folkestone in 1929 affected 25 to 30 persons, the vehicle being lemonade made from fresh lemons. The third in 1932 was in a London hospital

and affected 65 nurses, again from lemonade made from fresh fruit. In each instance the antimony was derived from enameled vessels. W.E.R.

Attempts to discover enamel highly resistant to acids. H. J. KARMAUS. *Sprechsaal*, **67** [21], 311–13 (1934).—With increased silica content the acid-stability is greatly raised, but not rectilinearly; it shows marked minima and maxima. Replacement of silica by boric acid increases solubility except when boric acid is used to replace alkalis. The chemical resistance of the oxides to acids and the solubility of salts produced by the acid attack greatly influence acid resistance. This is especially true with NaF crystals, which are precipitated in a finely dispersed state as opacifier, and of other opacifiers except tin oxide. The addition of clay lowers acid resistance. The technique of highly resistant enamels does not differ greatly from the usual methods of enameling. Several highly resistant enamel batches are discussed. M.V.K.

Black spots in enamels. ANON. *Emaillerie*, p. 5 (June, 1934); abstracted in *Verre & Silicates Ind.*, **5** [16], 311 (1934).—Black spots in enamel coats are caused chiefly by the presence of tiny particles of iron. Improved mills with vulcanized rubber and the use of magnetic separators are discussed. M.V.K.

Blisters in enamel due to weld seams. M. V. SCHWARZ AND F. GOLDMANN. *Forschungsarb. Metallkunde Röntgenmetallogr. Folge*, **11**, 1–9 (1934); abstracted in *Chem. Zentr.* **i**, 2333 (1934).—One chief reason for the formation of enamel blisters is the presence of cementite in the grains of the coarse-grained sheet iron. To avoid these, the sheet iron must be rolled over or under the critical temperature, or the subsequent annealing must be performed above the transformation temperature. M.V.K.

Characteristic defects when enameling cast iron. HUGO SCHULZE. *Glashütte*, **64** [21], 330–32; [23], 387–90 (1934).—Cast-iron defects which produce enamel defects are (1) wrong composition and mixing; (2) Kish graphite which produces a blistery enamel and an enamel running down in drying; (3) white cast-iron spots promoted by low temperature of the liquid iron and high sulfur content; (4) "sudoriphic balls," due to liquation because of pressure; (5) porous and spongy cast iron producing crater-like depressions, blisters, and pores in the enamel; (6) "cold welds" to which the enamel does not adhere or is covered with fissures; (7) "dust welds," due to defective molding sand, which produce the same defects as do porous cast iron; (8) slag inclusions producing star-like cracks in the enamel; (9) blisters, hollow spaces, "pipes" (in ingots) in cast iron, first noticeable on firing the enamel, which produce enamel flaws and splintering; (10) riveted or welded cast iron which often contains half-opened blisters; (11) construction defects of the molds; (12) oxidation of the raw cast iron produced by too moist molding sand; (13) defects due to unsatisfactory cleansing and grinding of the cast-iron surface. Illustrated. M.V.K.

Clay instead of feldspar. VIELHABER. *Emailwaren-Ind.*, **11** [33], 273–75 (1934).—Difficulties encountered when replacing feldspar by other materials in enamel batches are discussed. Examples of calculations are given. Enamels produced from kaolin, soda, and quartz have advantages over those containing feldspar. M.V.K.

Consistency testing methods. J. T. IRWIN. *Enamelist*, **11** [12], 10–13 (1934).—An old method for testing the consistency of enamels is the finger test of experienced workers. In another method a spoon with different sized holes is used and consistency is judged by the size of the largest hole over which a film of enamel remains. Checks on the dipping weight and the time required for excess enamel to drain off are also used. While enamel slips are not viscous many shops control enamel consistency by determining the "viscosity." The Gardner mobilometer and the Bingham plastometer are used for determining consistency but are better suited for laboratory than for plant control. The Rouse and Shearer plastometer is more practical. An electrical viscosimeter, which depends on the variation in the amount of electrical energy required to move a rotating circular plane perpendicular to the driving shaft through the enamel slip with variations in consistency, was found by tests to be unsuited as a control instrument in enamel shops. The advantages and disadvantages of these methods are pointed out. Illustrated. E.J.V.

Continuous vitreous enameling furnace. IV. F. S. MARKERT. *Enamelist*, **11** [11], 14–16 (1934).—In improving the exterior, common brick were replaced with a welded steel plate shell, proper insulation being used behind the fire brick. All plates were arc-welded to the structural framework so that the resulting furnace shell was an integral unit permitting no shifting, sagging, or movement of any kind. A larger amount of the less expensive but more efficient insulating powder could be used in the walls without danger of its sifting through or leaking out. The foundation paving was increased and insulated, and the entire furnace was set on a ventilated bottom consisting of alternate piers and spaces across the width. The conveyer unit was changed so that it was lighter and less bulky and gave better service. Types of oil or gas burners installed were dependent on the user's preference. The low pressure air and oil-burner installation and the premix natural and artificial gas units are described. Control features are also described. **V.** *Ibid.*, **11** [12], 18–20 (1934).—To eliminate a tendency toward longitudinal drafts or air currents within the preheat and cooling zones which affected temperatures within the firing chamber an air seal was installed at the front. The interior air curtain was installed to improve the transfer of heat from the fired ware to the unfired ware in the preheat and cooling zone. Although enclosing the roof slot with an insulated housing resulted in a fuel saving, it prevented the escape of gases freed during the firing of the enamels and affected the gloss thereof; therefore it was discontinued. To permit damper adjustment for minimum burner capacity an automatic motor-operated check damper which operated coincident with the burner-control mechanism from the same control instrument was installed. For Part III see *Ceram. Abs.*, **13** [10], 250 (1934). E.J.V.

De-enameling. VIELHABER. *Emailwaren-Ind.*, **11** [33], 275–76 (1934).—Methods of removing enamel by means of hydrofluoric acid, heated sulfuric acid, and alkaline bath are discussed and disadvantages are dealt with. M.V.K.

Defects in enameled kettles. HANS SCHULZE. *Glashütte*, **64** [9], 154–57 (1934).—Cases from practice showing

that defects in enameled cast-iron kettles are chiefly caused by a defective composition and treatment of the cast iron are described. A table showing the chief defects and their cause is given. Illustrated. M.V.K.

Development possibilities of the enamel industry. VIELHABER. *Emailwaren-Ind.*, **11** [32], 265–66 (1934).—The simplification and improvement of enamels and their production are described briefly. M.V.K.

Disintegration of cementite in cast iron as a function of time. E. H. KLEIN. *Stahl & Eisen*, **54** [32], 827–30 (1934).—Casting molds were preheated to various temperatures, and cast iron was melted at various temperatures. Samples were obtained showing the graphite either finely distributed or forming lamellae. The samples were annealed in nitrogen gas between 550 and 700°C. The thermal expansion and the decomposition of cementite were determined over a long period of time. The rate of decomposition follows the equation of a chemical reaction of first order, this being explained by the formation of graphite nuclei. The graphite is enclosed by a ferrite halo at room temperature, and the graphite passes through this halo by diffusion when being annealed. Cementite will decompose more rapidly in samples containing graphite finely distributed than in those containing graphite lamellae. The rate of decomposition increases with the temperature following a logarithmic formula. W.M.C.

Enamel blisters and their causes. LUDWIG STUCKERT. *Forschungsarb. Metallkunde Röntgenmetallogr. Folge*, **11**, 25–46 (1934); abstracted in *Chem. Zentr.*, **i**, 2333 (1934).—S. describes various reasons for the appearance of blisters in enamels and means of preventing them. M.V.K.

Enamel painting. MATH. BECKER. *Emailletechnische Monats-Blätter*, **10** [7], 78–79 (1934).—The methods of (1) hand painting, (2) stencil and spray painting, and (3) decalcomania are discussed. M.V.K.

Enamel as protection against corrosion and for ennobling metal surfaces. LUDWIG STUCKERT. *T. Z. prakt. Metallbearb.*, **44**, 29–31 (1934); abstracted in *Chem. Zentr.*, **i**, 2333 (1934).—The requirements of enamels are summarized. M.V.K.

Enameled cast iron and its testing. A. RADEMACHER. *Mitt. Forschungsanstalt. Gutehoffnunghütte Konzern*, **2**, 19–28 (1934); abstracted in *Chem. Zentr.*, **i**, 3783 (1934).—The quantities of the main impurities present in good cast iron to be enameled and their effect are described. The composition of typical majolica enamel is given. Heat stability is tested by heating the finished piece or by dripping cold water on the heated ware. Impact strength is tested with a weight of 374 g. The damages due to shock are classified as follows: (1) beginning of the visible injury, (2) first splintering, (3) visibility of the white coat, and (4) visibility of the ground. M.V.K.

Enameling cast iron by the wet method. H. LANG. *Glashütte*, **64** [30], 498–500 (1934).—While the enameling of sheet iron is always based on the same principle, cast iron is enameled by (1) the powder method, (2) the wet method, and (3) a combination of both. The principle of wet enameling of cast iron is basically similar to that used in sheet-iron enameling: a wet coating of the ground enamel and on this the coat enamel. Types of ground enamel are the fritted ground, fused ground, and water ground (fused ground of very thin consistency). The coat enamel is opaque or transparent (majolica). The preparation of cast iron for enameling and the application of the three kinds of ground enamel are described in detail. M.V.K.

Fishscales. H. SCHAARSCHUH. *Glashütte*, **64** [13], 219–20; [14], 223–24 (1934).—Fishscales appear chiefly in enamels adhering well (1) as small cracks (1 to 2 mm.) on the surface of the ground enamel, (2) as small half-moon shaped particles spit out from the ground enamel, and (3) as cracks reaching to the sheet iron. Various theories and investigations dealing with the cause of fishscales are discussed and the transformation of a body from the molten into the solid state is described. The fired ground enamel is not uniform in composition or in cubic coefficient of expansion. It has greater expansion in the layer next to the iron and in the iron spots formed by the dissolving of iron by cobalt silicate. These spots surrounded by ground enamel cause stresses in the ground enamel because of a different expansion; the stresses cause a breaking up of the enamel. The spots, saturated with iron, raise the undercooling and tend to form crystals. If this tendency occurs when the enamel is already solid and the spots are not yet solidified, sudden changes of volume (connected with crystallization) result in stresses. When these stresses exceed admissible limits, cracks 1 to 2 mm. long occur in the enamel but do not reach the sheet iron. The shock connected with the release from stresses effects a further cracking on the edges of the fissure, and half moon splinters are spit out. Fishscales did not appear when quartz and borax or boric acid were added to the mill but reappeared when these additions were omitted. The free acids (SiO_2 and B_2O_3) accelerate the dissolving of iron particles especially when not previously smelted into the enamel. A saturation is not reached, hence there is no crystallization or formation of fishscales. M.V.K.

Fluorine loss in enamel melts. A. THÖRMER. *Keram. Rund.*, **42** [35], 433–35 (1934).—Based on comparative results from three enamels with a different fluorine content, different fluxes, and different melting time, hydrogen, besides the other substances suitable for combining fluorine, was found to have a special influence on the amount of fluorine lost and on the effect of the part remaining in the melt. M.V.K.

"Foggy" dream of enameling. CARL G. STUECKEN. *Ceram. Ind.*, **23** [4], 198 (1934).—S. suggests cooling pickled or sandblasted parts below freezing, then passing them through a chamber into which ground or cover-coat enamels are blown in a fine vapor or fog. Controlled condensation of this fog on the cold metal would result in an even coat of enamel. The human factor of the sprayer and the dipper would be eliminated. Possible advantages of this method are pointed out. E.J.V.

German raw materials. VIELHABER. *Emailwaren-Ind.*, **11** [32], 266–67 (1934).—Data are given on raw materials used in enameling and found in Germany, including tin oxide, antimony oxide, zircon, borax, soda, fluorspar, cryolite, clay, feldspar, and pyrolusite. M.V.K.

Lithium oxide in enamel. VIELHABER. *Emailwaren-Ind.*, **11** [32], 267–68 (1934).—The use of lepidolite and other minerals containing lithium and its effect in glass melts are discussed. M.V.K.

Majolica enameling of cast-iron stoves in one firing.

FRANZ BERNDS. *Glashütte*, **64** [27], 453–54 (1934).—Cast-iron ground enamels permitting the executing of majolica enameling in one firing are described with special regard to a leadless, white, bright, ground enamel for a wet coating. Details are given. M.V.K.

Physical testing laboratory. M. G. AMMON. *Enamelist*, **11** [12], 13–14 (1934).—Tests on porcelain enamels in the new physical testing laboratory of the Ferro Enamel Corp., Cleveland, Ohio, and equipment for making them are described. They include accelerated weathering, heat-shock, abrasion, and impact tests, adherence of ground coats, surface hardness, and cross-bend tests, and dry-film strength, coefficient of expansion, and reflectivity or opacity measurements. Illustrated. E.J.V.

Porcelain enamel in new fields. R. A. WEAVER. *Enamelist*, **11** [12], 8 (1934).—W. points out that the "ripest" of new uses for porcelain enamel is the modernization of store fronts. E.J.V.

Reboiling of sheet-iron ground-coat enamels. A. I. ANDREWS AND R. E. MULLADY. *Jour. Amer. Ceram. Soc.*, **17** [11], 346–48 (1934).

Sodium fluosilicate. P. FERRAZZI. *Centro Studi Ceramici*, **1** [1], 16 (1934).—Sodium fluosilicate, Na_2SiF_6, is a natural product of great purity, is constant, and can be used as flux or opacifier in place of cryolite which must be made synthetically or imported in Italy. M.V.K.

Solubility of alkalis in wet grinding of enamel as a means of operating control. W. DAWIHL. *Keram. Rund.*, **42** [17], 207–208 (1934).—The alkali losses during grinding can be determined by separating the slip with neutral NaCl and titrating with 1 *N* HCl. The consumption of HCl has a characteristic curve according to the grinding time and depending on the state at which the homogenizing of the enamel has been interrupted during melting. M.V.K.

Survey of promising new markets for porcelain enamel. ANON. *Enamelist*, **11** [12], 16–17 (1934).—Assuming that 1% of asphalt roofing could be replaced by porcelain enameled shingle, a 15% increase in the porcelain enameling industry is possible. The three types of porcelain enameled shingles on the market are described. Installations of these products are shown. E.J.V.

Testing cooking utensils for cooking-stability. VIELHABER. *Emailwaren-Ind.*, **11** [29], 243–44 (1934).—All present methods do not give a definite picture of the behavior of enamel in housekeeping. Examples from practice are given. M.V.K.

Testing enamel coatings. FREITAG. *Apparatebau*, **46**, 33 (1934); abstracted in *Chem. Zentr.*, **i**, 3251 (1934).—Electric current and phenolphthalein are suggested for determining fissures in enamel coats. Acid-stable enamels are treated 10 times with a 20% hydrochloric acid solution and quenched between the treatments. M.V.K.

Testing enamelware for cooking and acid-stabilities. W. DAWIHL. *Keram. Rund.*, **42** [22], 271–72 (1934).—Four tests on the cooking stability of cooking ware were made and the results are compared. Acid-stability was tested by means of boiling with 10% acetic and oxalic acids; the attack of the latter was stronger. Boric acid volatilized during the boiling down of the acids. The enamels treated were weighed to determine exactly the results of the testing. The ware treated with the acids could be colored with methyl blue and could be distinguished. M.V.K.

Viscosity and reboiling of blue ground coats. R. R. DANIELSON AND J. D. TETRICK. *Jour. Amer. Ceram. Soc.*, **17** [11], 343–45 (1934).

Water-cooled dip tanks. HERMAN F. GILBERT. *Enamelist*, **11** [12], 15 (1934).—G. considers uniformity of the proper temperature of the dipping enamel more important to the slip or consistency of the enamel than any other known property, not excepting clay or borax, to the mill addition. Tests on a properly set-up enamel batch and on a mill of enamel, having neither clay nor borax to add to its draining qualities, in a temperature controlled tank and in an uncontrolled tank showed that either dipped perfectly in the controlled tank and both broke down in the uncontrolled tank. By installing a water-cooled dip tank, with an electric cooling system to maintain the dipping enamel at 68°F, it was possible to dip for 12 hr. without having an appreciable variation in the slip. The suspension of the enamel in the tank is improved, and the smoothness and uniformity of the enamel coating on the ware is materially better. E.J.V.

White ground coats. JAMES D. TETRICK. *Jour. Amer. Ceram. Soc.*, **17** [11], 349–56 (1934).

PATENT

Sink and similar structure and method of constructing. SAUL BLICKMAN. U. S. 1,974,794, Sept. 25, 1934.

Glass

Alumina in the glass batch. HUGO KÜHL. *Glashütte*, **64** [29], 479–81 (1934).—The assumptions that large amounts of pure alumina make the glass difficult to melt in the presence of small amounts of lime and alkalis as fluxes and that alumina easily tends to form stones and always to form streaks are discussed. It is shown by examples that the introduction of alumina in sufficient quantities to greatly affect the glass properties is easily performed when the batch contains an adequate amount of alkalis and lime. It is proved on the basis of melting experiments that alumina in the form of minerals containing natural alumina does not injure the quality of glass and presents great advantages. When suitable minerals are used, the glass is easily melted; 1.5 to 3% Al_2O_3 improves the homogeneity of the batch; larger additions are unnecessary. M.V.K.

Architectural uses of glass. GEORGE LOVELL. *Jour. Soc. Glass Tech.*, **18** [70], 106–11 (1934).—L. deals with uses of flat and bent glass, including surface treatments of different kinds and their application as a decorative medium in architecture. Exteriors and interiors of buildings, methods of illumination, and the use of mirrors are discussed. Special reference is made to nonreflecting windows.

Artistic table glass. JAMES H. HOGAN. *Jour. Soc. Glass*

Tech., **18** [70], 96–105 (1934).—It is necessary to study the technique of glass manufacture before attempting to design the form of any article. A shape obtained in a simple and straightforward manner is best. Molded glass presents special difficulties, notably in obtaining equal distribution of the glass. Pressed glassware has a great future as a mass-produced article. During the 18th Century British glassmakers developed a beautiful and individual design based on principles of simplicity and utility. It was destroyed by the desire to imitate foreign patterns. Shapes and forms based on typically British style should be encouraged.

Can one see better in colored light? W. ARNDT. *Z. tech. Physik*, **15** [8], 296–301 (1934).—A. discusses a number of physiological rules which play a rôle in the distinction of different objects by the human eye, in the fatigue of the eye, etc. Colored and monochromatic light sources have been used for the tests, but no general conclusions are drawn. W.M.C.

Carbon or sulfur yellow and selenium red glasses. LUDWIG SPRINGER. *Glashütte*, **64** [24], 399–401 (1934).—The practical results of studies of S. on carbon or sulfur yellow glasses and selenium glasses (*Ceram. Abs.*, **11** [2], 94 (1932); **12** [2], 52 (1933)) and those of Weckerle on the coloring of glasses by copper, selenium, and sulfur (*ibid.*, **13** [4], 84 (1934)) are compared and discussed. S. found that materials containing carbon alone without sulfur may color the glasses yellow. Only in the presence of carbon does iron sulfide produce a stable yellow coloring. The coloring power of graphite is in reverse proportion to the carbon content, *i.e.*, the purest graphite colors the least, whereas its coloring power greatly increases with the iron or sulfur content of the glass. Weckerle found that carbon colors soft glasses only, while sulfur glasses are colored by iron sulfide and not by colloidal S as heretofore assumed. With regard to selenium pink glasses, S. found that an increased addition of Se does not yield a deeper coloring, but changes it to yellow-brown. Elementary Se always colors better than selenite of soda. Potash-lime glasses are better colored than soda glasses; lime-zinc glasses yield yellow-brown colors. Saltpeter strengthens the color with selenite of soda, but destroys it with Se. Arsenic has the same effect. Weckerle found that rose glasses are obtained only with a neutral melting and that an addition of a reducer always produces a brown color tone. A selenium ruby glass is obtained only in the presence of ZnO, Cd, and Se; the presence of sulfur is not necessary. S. found, on the other hand, that soda-lime glasses with selenite of soda were colorless (with or without arsenic), while elementary Se produced a strong selenium ruby destroyed by arsenic. Potash-lime glasses with the same additions never produced red, but only pink. Lime-zinc or pure zinc glasses yielded ruby red with elementary Se, which was weakened by As; selenite of soda did not color. M.V.K.

Chemical durability of flat glass. J. S. GREGORIUS. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 188–91 (1934); *Glass Ind.*, **15** [9], 209 (1934); *Nat. Glass Budget*, **50** [21], 14 (1934). E.J.V.

Chemical durability of glass. W. E. S. TURNER. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 212 (1934); *Glass Ind.*, **15** [9], 210 (1934); *Nat. Glass Budget*, **50** [21], 15 (1934). E.J.V.

Chemical durability of glass and methods for its measurement. G. W. MOREY. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 214 (1934); *Glass Ind.*, **15** [9], 206–207 (1934); *Nat. Glass Budget*, **50** [21], 14 (1934). E.J.V.

Chemical durability of soda-lime glasses. O. G. BURCH. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 212 (1934); *Glass Ind.*, **15** [9], 209 (1934); *Nat. Glass Budget*, **50** [21], 15 (1934). E.J.V.

Constitution and colors of glass. WOLDEMAR WEYL. *Sprechsaal*, **67** [27], 405–406 (1934).—W. reviews researches made at the Kaiser Wilhelm Institute of Silicate Research and deals with the effect of various factors on the properties of glass, its coloring, and theories of the glassy state. M.V.K.

Constitution of glass. GEORGE W. MOREY. *Jour. Amer. Ceram. Soc.*, **17** [11], 315–28 (1934).

Cords and methods of eliminating them. A. A. YAKHILEVICH. *Jour. Opt.-Mechan. Ind. U.S.S.R.*, No. 5, p. 13 (1933).—Various shapes of stirrers and different trajectories of their motion were studied as well as the elimination of vortex in the liquid glass (phenomena which were considered to be a source of cordiness), but this did not solve the problem. Further research should develop along investigation of (*a*) the process of stirring, and (*b*) the process of cooling, since pure glass, obtained after melting, sometimes became cordy during cooling, owing to certain thermal and external mechanical phenomena. This view was based on a new conception of the nature of cords, opposed to the current opinion that the cord is a product of inhomogeneity in the chemical composition of the body of glass. The idea was developed that the cord was homogeneous as to its chemical composition, but different in structure, *i.e.*, in the relative disposition of molecules. Homogeneous samples of glass free from cords were fused together, and it was observed that cords were formed about the weld after cooling, which was thought to be explained by a different physical state from that of the main body of the glass. (*J.S.G.T.*)

Corning plans new 200-inch mirror disk. ANON. *Amer. Glass Rev.*, **53** [44], 9 (1934).—Plans are now under way for pouring a twin mirror for the first 200-inch mirror cast last March at Corning. This mirror will be identical in every respect to the first one except that the mold construction will be more rugged. M.C.S.

Corrosion in contact with glass. R. B. MEARS AND U. R. EVANS. *Trans. Faraday Soc.*, **30** [5], 417–23 (1934); *Physik. Ber*, **15** [18], 1474 (1934).—Metal in contact with a nonconductor, *e.g.*, glass, which can not function as a cathode, is corroded at the contact. Examples of steel in contact with glass and other kinds of steel are described. M.H.

Corrosion of glass. W. C. TAYLOR. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*,

23 [4], 188 (1934); *Glass Ind.*, **15** [9], 205–206 (1934); *Nat. Glass Budget*, **50** [21], 14 (1934). E.J.V.

Decolorization of glass. PHILIPPE GRACH. *Rev. prod. chim.*, **37**, 289–93, 326–29 (1934).—A review covering the influence of temperature, furnace atmosphere, and glass composition on the state of oxidation of Fe in glass, decolorization by chlorides, Mn, Ni, Co, Se, Nd, Ce, and the effect of radiation on the decolorized glass is presented. (*C.A.*)

Design of glass bottles. EDWARD MEIGH. *Jour. Soc. Glass Tech.*, **18** [70], 122–27 (1934).—The artist is faced with considerable limitations in undertaking the design of glass bottles for modern use as containers and conveyers of commodities. These limitations are considered under material, method of manufacture, and purpose for which the ware is to be used. The difficulties are illustrated by reference to the automatically mass-produced bottle, certain types of which are so closely defined by the conditions of manufacture and of use that there is little scope for artistic treatment of form and they may be said to design themselves. M. concludes that it is essential for the designer of glass bottles to be associated intimately with the factory.

Destruction of optical glasses in tropics. H. W. ACTON. *Indian Med. Gaz.*, **68**, 688–89 (1933); abstracted in *Chem. Zentr.*, **i**, 2022 (1934).—One reason for the changes occurring in glasses of optical instruments is the growth of mushrooms. Oil of cinnamon proved to be a good protection, but not $CuSO_4$ or "gentian violet." M.V.K.

Determination of chemical resistance of glass by the emanation method. M. N. ROSTOVA AND V. G. VOANO. *Trav. inst. état. radium* (U S.S.R.), **2**, 135–36 (1933).—Hahn's method (*Ceram. Abs.*, **9** [4], 308 (1930)) was used. (*C.A.*)

Determining alkalis in soda-lime-silicate glasses by rapid method. SHIGEYUKI SHINKAI. *Jour. Soc. Chem. Ind.* [Japan], **37** [7], 378–80*B* (1934).—One-half gram is moistened and 10 to 20 cc. HF and 0.5 cc. of sulfuric acid are added. The solution is evaporated and heated over a free flame. If hydrofluoric silicates are present, Al and Ca are not completely precipitated. The residue is dissolved with a little HCl, treated with ammonium chloride, and heated to boiling; a surplus of ammonia is added. The precipitate is washed three times by decantation with hot water containing ammonia and ammonium nitrate and filtered; it is washed until free from sulfate. The filtrate is evaporated, heated to boiling, and precipitated by means of a boiling solution of ammonium oxalate. After standing 3 hr., the calcium oxalate is filtered off and washed with hot water containing ammonium oxalate. The filtrate is evaporated and 70 to 80 cc. nitric acid are added to decompose the ammonium salts. The solution is heated to boiling and then evaporated to dryness. The residue is dissolved with water, filtered, and washed with hot water. It is evaporated to dryness, heated to dull red, and weighed after cooling. The weight is $Na_2SO_4 + MgSO_4$. Mg is determined as usual and the corresponding weight of $MgSO_4$ is deducted from $Na_2SO_4 + MgSO_4$. M.V.K.

Durability of glass. II. ANON. *Glass Ind.*, **15** [9], 225–27 (1934).—The two concluding sections of the bibliography of literature on the relation of composition and durability and general information are presented. For Part I see *Ceram. Abs.*, **13** [11], 290 (1934). E.J.V.

Durability of glass containers. F. C. FLINT Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 187–88 (1934); *Glass Ind.*, **15** [9], 205 (1934); *Nat. Glass Budget*, **50** [23], 16 (1934). E.J.V.

Emilite, a new metal for glass molds. MILLER FOUNDRY CO. *Nat. Glass Budget*, **50** [16], 3 (1934).—A new glass mold metal believed to be superior to anything now used is described. It is supplied in fourteen analyses to meet the requirements of different installations. It is tough and resistant to corrosion and high temperatures. M.C.S.

Essentials of glass technology based on American practice. XIII. S. R. SCHOLES. *Ceram. Ind.*, **23** [4], 208–11 (1934).—Methods used in making "off-hand," paste-mold or turn-mold, and iron-mold or hot-mold ware are described. For Part XII see *Ceram. Abs.*, **13** [11], 290 (1934). E.J.V.

Flat glass. W. F. BROWN. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 187 (1934); *Glass Ind.*, **15** [9], 205 (1934); *Nat. Glass Budget*, **50** [21], 14 (1934). E.J.V.

Form, design, and decoration of glass. H. LLEWELLYN SMITH. *Jour. Soc. Glass Tech.*, **18** [70], 89–95 (1934).—Industrial art in relation to glassware aims at improving form and design. Decoration can not atone for bad construction. Glassware production is in a state of transition between a handicraft and a large-scale mechanical industry. The main factor in the creation and transformation of artistic styles is the unceasing conflict between tradition and innovation. The problem of manufacturers and designers is to produce good, simple, well-designed, and cheap glassware. Good design is essential to commercial success.

Glass from blast-furnace slag. LUDWIG SPRINGER. *Keram. Rund.*, **42** [21], 255–56 (1934).—Blast-furnace slag can be used advantageously for the manufacture of ordinary brown bottle glass and for yellow-brown glass for containing medicines. M.V.K.

Glass composition effect on the magnitude of the potential difference glass-solution. K. S. EVSTROPIEV AND N. V. SUIKOVSKAYA. *Trans. Opt. Inst.* [Leningrad], **10** [90], 23–35 (1934).—By the electrometric titration method, the dependence of the potential of phases of glass-solution on the p_H of the solution was studied. The measurements were made for 2-component glasses ($SiO + Na_2O$) and for some 3-component glasses (80% SiO_2 + 20% Na_2O + additions of CaO, MgO, BaO, PbO, ZnO, Al_2O_3, and B_2O_3). The effect of various cations on the potential of the glass was determined; the most severe effects are produced by additions of Al_2O_3, B_2O_3, and ZnO. An absorption theory of glass electrodes is developed. M.V.K.

Glass container design. KENNETH L. GRAHAM. *Jour. Soc. Glass Tech.*, **18** [70], 112–21 (1934).—Present conditions are reviewed from the viewpoints of the buyer, manufacturer, and designer. Factors governing the choice of closure are discussed. The designer should have personal contact with the glassmaker as well as with the purchaser. The advantages of originality and novelty are discussed, and the trick of deceptive capacity is condemned. Pottery shapes and ornamentation should not be repro-

duced by the glass designer. There should be stronger links between the glass manufacturer, the designer, and the consumer.

Glass flowerpots approved. ANON. *Amer. Glass Rev.*, **53** [45], 15 (1934).—The Department of Botany, Mass. State College, found that nonporous pots, including glass, were better for plant growth than porous pots. Nonporous pots do not produce a more acid soil than porous pots. M.C.S.

Glass industry of Norway and Sweden. W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **18** [70], 169–81 (1934).—Special references are made to social conditions, wages, technical equipment, and plants. See also *Ceram. Abs.*, **13** [6], 147 (1934).

Glass manufacturers exhibit American ware in Iowa. ANNA LANE DIXON. *Bull. Amer. Ceram. Soc.*, **13** [10], 289 (1934).—A bibliography for the study of American glass is given.

Glass progress dependent on chemists. A. SILVERMAN. *Ind. Eng. Chem., News Ed.*, **12** [17], 313–14 (1934).—The need for chemists in the glass industry in the technical control of raw materials, study of satisfactory substitutes, and development of new glass products, is emphasized. F.G.H.

Guiding lines for coloring glass. HUGO KÜHL. *Glashütte*, **64** [34], 569–71 (1934).—The composition of the glass is important in its decolorizing and coloring, and delicate coloring is possible only with technically colorless glasses. Methods used for improving the glass by coloring are (1) etching, (2) "tempering color," and (3) real coloring with the aid of glass oxide silicates dissolved in the glass melt. These methods are briefly outlined. The gradations of saturated colors to soft or delicate colors depend on the amount of pigment, the composition of the basic glass, and the purity of raw materials melted. In spite of difficulties encountered in glass coloring, it is possible to produce isochromatic glasses stained through of every color tone with a careful preparation of the batch and correct melting. M.V.K.

Hypothesis of the colloidal character of glass. ARNALDO MAURI. *Ind. Vetro & Ceramica*, **6** [7], 269–72 (1933); abstracted in *Centro Studi Ceramici*, **1** [1], 10 (1934).—After an examination of the hypotheses of various technicians, M. concludes that a change of the dispersed phase (inversion) is not unconditionally necessary for all devitrifications. M.V.K.

Indium reflects all colors of spectrum. ANON. *Nat. Glass Budget*, **50** [21], 16 (1934).—Indium-plated reflectors have the property of reflecting all the colors of the spectrum evenly. Indium is nontarnishable and provides a brilliant reflecting surface (said to be caused by its nearness to the center of the spectrum), exhibiting a blue that is not present in other metals. M.C.S.

Lens surfaces ground to millionths of an inch. EVERETT W. MELSON. *Abrasive Ind.*, **15** [8], 8 (1934).—The grinding of lens surfaces is probably one of the most exacting operations known to science. Surfaces are ground to within a millionth of an inch, light rays being used to measure this accuracy. Such precision grinding is accomplished through the careful selection of the grinding medium, usually silicon carbide. This material is accurately graded by gravity in a water suspension. Steps taken in the grinding operations are shown. M.C.S.

Lowering costs and speeding production in the glass industry. E. C. SULLIVAN. *Ind. Eng. Chem., News Ed.*, **12** [17], 314 (1934).—Electrocast glass-tank blocks consisting of corundum and mullite bonded with a small percentage of glass are discussed. Advantages gained through their application are described. See also *Ceram. Abs.*, **13** [5], 120 (1934). F.G.H.

Melting properties of raw materials used in glass manufacture. A. THÜRMER. *Keram. Rund.*, **42** [33], 406–408 (1934).—In a batch, CaO was replaced by lime raw materials, and alumina was introduced in the form of minerals containing it instead of SiO_2 so that in spite of the various raw materials used the glass synthesis remained the same. The melting time, rate of glass formation, and homogenization were studied through the determination of the grit solubility. Every raw material has its own melting behavior. The equilibria of the glass state do not always coincide with the ending of melting. Raw materials dissolving rapidly in the melt obstruct the homogenization, while glasses containing raw materials melting more slowly and expelling gas are usually homogenized at the end of melting. The tests show how to judge glass melts and to select the most suitable raw materials for a type of glass. M.V.K.

Metals suitable for melting with glass. W. F. BRANDSMA. *Physik. Ber.*, **15** [16], 1268–69 (1934).—The vacuum-tight melting of metal into glass (as required, *e.g.*, for X-ray tubes, etc.) can be obtained with Cu, Pt, Fe-Ni, and Fe-Cr. Expansion coefficient, adhesion to glass, heat conductivity, and low gas emission are of prime importance. An alloy of Fe with 25% Cr gives good results. M.H.

Metal-to-glass seal is sturdy and reliable. GENERAL ELECTRIC CO. *Ceram. Ind.*, **23** [4], 181 (1934).—Seals between glass and an alloy known as Fernico have been developed. E.J.V.

Microscales with glass. HORACIO DAMIANOVICH. *Ann. inst. investig. cient. tech.*, **2**, 85–90 (1931); abstracted in *Chem. Zentr.*, **i**, 2454 (1934).—Glass threads of 0.015 to 0.030 mm. thickness instead of quartz fibers and an optical system instead of the usual speculum scale were used. The glass threads are very resistant, and the scales are more sensitive and simpler than ordinary quartz scales. M.V.K.

Old English glass. No. 53. British glassmaker abroad. F. BUCKLEY. *Glass*, **11** [7], 266 (1934).—B. describes the emigration of the old English glassmakers to various countries in Europe and the adversities suffered. **No. 54. Famous London glasshouse.** *Ibid.*, **11** [8], 308 (1934).—A brief historical sketch relates important occasions in the life of the White Friars Glasshouse. Over 200 years old, and one of the oldest London glasshouses, this flint glass plant survived many harrowing experiences. For No. 52 see *Ceram. Abs.*, **13** [8], 205 (1934). M.C.S.

Opacity standards. D. B. JUDD. *Jour. Research Nat. Bur. Stand.*, **13** [3], 281–91 (1934).—The opacity of a sheet of any material (paper, cloth, porcelain, etc.) may be specified by the contrast-ratio method. According to this method the reflectance of the material backed by a perfectly absorbing surface divided by its reflectance when backed by a highly reflecting material such as magnesium

oxide is taken as an index of opacity. Magnesium oxide, however, is not commonly used as the white backing because of its fragility; the white backing is not placed in actual contact with the sample. Because of these and other sources of error, opacimeters frequently give erroneous results. Standards of opacity made of permanent material serve to check and to calibrate such instruments. Such standards made of opal glass, the theory of their application, and results of tests by their use are described. R.A.H.

Permeability of atmosphere and glasses to ultra-violet rays. J. Dobtsch. *Anales soc. espaň. fis. quim.*, **32**, 64–71 (1934); abstracted in *Chem. Zentr.*, **i**, 3250 (1934).—The permeability of glasses was studied. The presence of Ti and V in glasses was determined spectrometrically. The use of thick-walled glasses is a certain protection to the action of short rays. M.V.K.

Physical analysis of glass. Mario Conti. *Ind. Vetro & Ceramica*, **6** [9], 386–90 (1933).—The most important systems used in the physical analysis of glass, their underlying principles, and methods of procedure are discussed. See also *Ceram. Abs.*, **13** [6], 145 (1934). M.V.K.

Physicochemical processes occurring during melting of potash-lead-silica glasses. M. A. Besborodov, A. A. Appen, T. F. Korzukhina, E. P. Khodikel, and G. A. Shinke. *Keram. i Steklo*, **10** [1], 26–32 (1934).—Four methods were used to determine the processes: (1) determining the total loss in weight of the batch on heating, (2) analysis of gases escaping from the batch at various temperatures, (3) fractional analysis of the batch at different temperatures, and (4) microscopic analysis. The results are shown in curves which are discussed. The reaction of silicate formation ($K_2CO_3 + SiO_2$) begins between 500 and 600° and proceeds energetically with the escape of CO_2 between 600 and 700°; at 800° this reaction is ended. According to data on the total loss of weight and analysis of gases, the processes are ended at 800° and the curves become horizontal; the fractional chemical analysis and the microscopic study, however, show that the processes continue. Between 600 and 700° there is an inter-reaction between PbO and SiO_2 with the formation of PbO silicates and potash-lead compounds. Only a part of SiO_2 goes into reaction below 1000°. At 1200° the whole melt becomes isotropic; no quartz grains are visible. The final index of refraction of the glass is 1607 at 1200°. The homogeneity is obtained here only by diffusion. See also *Ceram. Abs.*, **13** [3], 58 (1934). M.V.K.

Preparation of high melting-point glasses. M. K. Hoffmann. *Fortschr. Mineral., Krist., & Petrog.*, **17** [1], 42–43 (1932).—Clean glasses could be obtained by melting in a magnetically controlled arc and by quenching in water, phenacite, beryl, or mullite components, the two former having refractive indices near 1.56 and 1.52, smaller than the values for the crystals. By mixing crushed crown glass with ¼ powdered ($ZrO_2 + SiO_2$), arcing, and quenching, a transparent, hard, and high melting-point glass was obtained. Similarly, MgO, BeO, ThO_2, and ZrO_2 could also be melted with a glass to give this high melting-point glassy material. The amount of mineralogical component varied from 10 to 50%, approximating mainly to 33⅓%. (*J.S.G.T.*)

Principles of light signaling in daylight and the physical problem of glasses for signals. P. Gilard, P. Swings, and H. Brasseur. *Rev. universelle mines*, **10** [7], 173–78; [8], 209–14; [9], 234–41 (1934).—A report on the methods of light signaling used on the Belgian railroads is given. The form, shape, and color of the glass plates used are discussed. A report on the absorption of light and the wave-lengths of the light transmitted by many glasses of various compositions is reviewed. L.T.B.

Progress in the glass industry in 1933. Oscar Knapp. *Glashütte*, **64** [28], 463–65 (1934).—A review is given of researches dealing with (1) effect of gases on the properties of glasses, (2) diffusion of silver and copper in glass, (3) volatilization of silica, (4) evaporation of potash-silica glasses, (5) effect of alkali carbonates on silica and alkali silicates, (6) action of lime on silica, (7) physical properties of soda-potash-lime-silica glasses, (8) effect of alumina on alkali-lime-silica glasses, (9) the system stannous oxide-silica, (10) adsorption of atomic hydrogen on lead and lime glasses, (11) changes in the alkaline solubility of fire-polished glasses through the burning of alkalis, (12) lowering of alkalinity of soda-lime-silica glasses, (13) solubility of alkali-borosilicate glasses, and (14) time dependence of water attack on glass. Bibliography. See also *Ceram. Abs.*, **13** [11], 292 (1934). M.V.K.

Raw materials used in glass manufacture. II–IV. Anon. *Glass*, **11** [6], 220–23; [7], 260–63; [8], 300 (1934); for Part I see *Ceram. Abs.*, **13** [8], 205 (1934). M.C.S.

Refining crystal hollow glass by electrolytic silver plating. Anon. *Oberflächentechnik*, **11** [16], 176–78 (1934).—A method for decorating, ornamenting, etc., crystal glassware is described. The glass is first covered with paraffin on the parts not to be silvered in an etching bath of 1 part HF, 2 parts H_2SO_4, and 8 parts H_2O; it is left in the bath until the pattern is sufficiently clear. After removal of the paraffin, the pattern is coated with Ag powder and fired in a muffle furnace. After this, the glass is silver plated in a bath containing at least 30 g. Ag per kg. bath with not more than 0.3 amp./dm.^{2} current density and 1.2 volts at 15°C. Equipment and procedure are described in full. M.H.

Refractive power of quartz glass in the short wave infrared. C. Muller and A. Wetthauer. *Z. Physik*, **85** [9–10], 559–60 (1933).—The indices of refraction of quartz glass were measured for wave-lengths between 0.511 and 2.595μ. Curves are included showing a comparison of the indices of refraction of rock salt, crystalline quartz, and fluorspar for the same wave-lengths. L.T.B.

Researches dealing with the glass flow in tank furnaces. Oscar Knapp. *Glashütte*, **64** [36], 599–602 (1934).—A brief review of various studies and experiments to ascertain the glass flow in tank furnaces is given. M.V.K.

Silesian glassmelting at the beginning of the 19th Century. W. Ganzenmüller. *Sprechsaal*, **67** [31], 463–65; [32], 480–82; [33], 496–98; [34], 511–12 (1934).—A historical review is given of manufacturing methods of various kinds of glassware at the beginning of the 19th Century. M.V.K.

Solvents for the safety-glass industry. Th. Pesch. *Chem.-Ztg.*, **56** [104], 1033–34 (1934).—A general discus-

sion of various properties required of solvents used in the production of safety glass by the wet method is given. The necessity of an exact knowledge of the evaporation figure and volatility of various substances mixed with solvents is emphasized. M.V.K.

Special types of chemical durability. M. E. NORDBERG. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 191 (1934); *Glass Ind.*, **15** [9], 209–10 (1934); *Nat. Glass Budget*, **50** [21], 15 (1934). E.J.V.

Stresses and strength of glass bottles. K. H. BORCHARD. *Glashütte*, **64** [10], 169–71 (1934).—B. found that only very high stresses, especially local stresses, inclusions of foreign material, and defective spots endanger the strength of bottles, but the effect of light stresses on the mechanical properties should not be overvalued. It is important whether the stresses due to cooling counteraffect the mechanical requirements or are added, whereby the danger of rupture is increased. The results are tabulated. See also *Ceram. Abs.*, **13** [10], 256 (1934). M.V.K.

Surface electrical properties of glass in relation to chemical durability. E. M. GUYER. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 212 (1934); *Glass Ind.*, **15** [9], 210 (1934); *Nat. Glass Budget*, **50** [23], 16 (1934). E.J.V.

Testing glass ampoules for pharmaceutical products. E. BERTARELLY. *Rend. ist. lombardo sci.*, **66** [2], 1053–59 (1933); abstracted in *Chem. Zentr.*, **i**, 2472–73 (1934). M.V.K.

Testing glass containers for chemical durability. W. E. S. TURNER. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 212–14 (1934); *Glass Ind.*, **15** [9], 210 (1934); *Nat. Glass Budget*, **50** [23], 16 (1934). E.J.V.

Thermal resistance of glass. R. D. *Verre & Silicates Ind.*, **5** [16], 304–306 (1934).—The formula of Winkelmann and Schott for evaluating the thermal resistance of a given glass and tests for evaluating the degree of annealing of plate and hollow glassware are briefly discussed. M.V.K.

Time element in glass testing. FRANK W. PRESTON. *Glass Ind.*, **15** [9], 217 (1934).—Glass, like most other materials, "fatigues" under load. A load or pressure which it will support for a moment may break it if sustained for an hour, and a load safe for an hour may be unsafe if sustained for a day or a week. It is useless to quote the "breaking strength" or "modulus of rupture" of glass unless at least an approximate idea of the duration of the test or of the rate of loading is given. Examples of kinds of glassware which must sustain loads for a long period are cited. The rate of decrease of strength with time is not the same for all glasses, nor for all articles made of a given glass. It follows that the strength of glass can not be given by a single figure as so many pounds per square inch. It will apparently be necessary to give the breaking strength for a load enduring one minute, and another figure which will permit an estimate of its strength if the load endures for a day or a month or a year. Instantaneous pressure tests, *i.e.*, pressure tests under continually increasing load, can not be entirely satisfactory if the whole test is over in a few seconds. E.J.V.

Time factor in durability tests. DONALD E. SHARP. Presented at summer meeting of Glass Division, Amer. Ceram. Soc., Hammondsport, N. Y., Sept., 1934; abstracted in *Ceram. Ind.*, **23** [4], 214 (1934); *Glass Ind.*, **15** [9], 207 (1934); *Nat. Glass Budget*, **50** [21], 14 (1934). E.J.V.

Toughened plate glass. L. VON REIS. *Z. Ver. deut. Ing.*, **77** [23], 615–18 (1933).—Glass is almost exclusively molded in the liquid or viscous state and then cooled uniformly. Uniform slow cooling yields ordinary glass which is practically free from strain; uniform rapid cooling yields a toughened glass which has a higher strength for mechanical and thermal resistance. A new air cooling process for quenching plate glass and toughening it thereby is outlined which consists in suspending the glass vertically, heating it above its softening point, and then cooling by air. Drawings of the cooling system are included. The strengths of ordinary glass and of that toughened by this new process are compared. Mechanical requirements of safety glass and of other glasses of unusual specifications are discussed. L.T.B.

Ultra-violet transmission of thinly blown glass windows. H. KLUMB AND T. HAASE. *Z. Physik*, **76** [5–6], 322–27 (1932).—The absorption of ultra-violet rays by a series of commercial glasses is reported. The results in percentage transmission of the rays are tabulated for glass thickness of 30μ over a range of wave-lengths. The mechanical strength and gas penetrability of the glasses were studied. L.T.B.

Viscosity and electrical conductivity of molten glasses. C. L. BABCOCK. *Jour. Amer. Ceram. Soc.*, **17** [11], 329–42 (1934).

Volatilization of lithium oxide at high temperatures from lithium oxide-silica glasses. ERIC PRESTON AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **18** [70], 143–68 (1934).—The glasses were pure, ranging in composition from 10.12 to 50.09% Li_2O (18 to 66 mol. %), and were characterized by a strong tendency toward devitrification. Under the experimental conditions used, the range of volatilization losses during the first 20 hr. of heating in each case was (in mg./cm.^{2}) at 1400°, 2.25 to 120; at 1300°, 0.6 to 46; at 1200°, 0.15 to 5.3. At 1100°, owing to crystallization in all others, measurements were possible only with glasses containing 20.53 and 22.88% Li_2O. The temperature-volatility relationships approximated to a vapor-pressure law. The vapor pressures of the two highest members of the series were found to be for the 38.22% Li_2O glass, 0.50 at 1300° and 0.73 mm. Hg at 1350° and for the 50.09% Li_2O glass, 1.35 at 1300° and 3.74 mm. Hg at 1400°. A visible demonstration was given of the changing surface concentration of alkali as volatilization proceeded and of the existence of a concentration gradient throughout the melt. A graphical demonstration was also given of the changing surface concentration with time. From the volatilization-concentration relationships, the presence was deduced, in the molten glasses, of the compounds Li_2O2SiO_2, Li_2OSiO_2, and $2Li_2OSiO_2$. Further evidence of this was afforded by means of the

application to particular members of the series of the equation

$$\log \frac{A - 2x}{A} = -Kt$$

For glasses containing about 20 mol. % of each of the oxides K_2O, Na_2O, or Li_2O, it was found that molecularly these constituents were almost equally volatile at 1400°.

Yellow etching of glass by metal compounds. Otto Herfurth. *Diamant*, 56 [19], 217–18 (1934).—A general discussion of yellow etching of glass and the results of experiments of Springer (*Ceram. Abs.*, 11 [8], 446 (1932)), Heinrich (*ibid.*, 11 [4], 237 (1932)), and Schatt (*ibid.*, 11 [8], 446 (1932)) are presented. M.V.K.

BOOK REVIEWS

Construction and Operation of a Tank Furnace. B. F. Kuzmich. State Pub. House of Light Ind., Moscow, 1933. 96 pp. Price 1 R 80 k. There are only a few books published in U.S.S.R. completely devoted to glass-melting furnaces. The necessary data for the design, calculation, and construction of tank and pot furnaces are scattered in books dealing with glass technology in its general aspects and in separate articles of the periodical literature. Therefore the publication of this practical book should be welcomed as a first attempt at systematization and joining in one volume of the necessary data for construction of industrial glassmelting tank furnaces. The first four chapters deal respectively with (1) grounds and foundations for furnaces, (2) materials used for constructing tank furnaces, (3) the basic kinds of furnace constructions, and (4) crowns, arches, and throats. The fifth chapter is of special value giving a detailed practical example of construction and calculations involved in the design of a 30 m. typical tank furnace for glass manufacture by the Fourcault method. It is of a particular interest today when the old plants making mouth-blown glass are feverishly undergoing reconstruction and new mechanized plants for flat glass manufacture by the Fourcault method are being erected. The last chapter tells how to put a newly constructed furnace into operation. This book, containing many reliable reference data, will be useful for those interested in the construction and operation of a tank furnace. S.I.Perkal

Glass Technique (Steklotekhnika). **Vol. I.** Published by G. Yu. Zhukovskiĭ, Gosudarstv. Khimiko-Tekhnich. Isdat., 1934. 234 pp. Price 4 R 25 k. This book is a compilation of the latest original researches dealing with the technology of glass, including (1) "Dependence of some properties of glass on its chemical composition," by G. Yu. Zhukovskiĭ; (2) "Conditions under which the batch separates into component parts," by G. Yu. Zhukovskiĭ and E. Z. Zhitomirskaya; (3) "Briquetting the batch," by G. Yu. Zhukovskiĭ and A. S. Pryanishnikov; (4) "Absorption of light by cobalt salts," by B. S. Shvetzov and A. M. Tankhilevich; (5) "Method of investigating the absorption of infra-red rays by glass," by K. P. Yakovlev; (6) "Determining the upper region of crystallization," by O. K. Botvinkin; (7) "Spiral-like rupture of glass rods," by M. A. Besborodov and K. V. Struve; (8) "Up-to-date state of glass decoloration," by F. H. Zschacke; (9) "Glass annealing," by S. G. Lioznyanskaya and S. I. Ioffe; (10) "Formation of sulfate lye in soda glass," by I. I. Kitaigorodskiĭ and Ya. A. Shkolnikov; (11) "Using rocks in glass manufacture," by Ya. A. Shkolnikov; (12) "Modern construction of glassmelting furnaces," by Fritz Eckert; (13) "Pyrometry in the glass industry," by K. G. Stepanenko; (14) "Relationship between t and E in platinum-rhodium thermoelements," by T. A. Popova; (15) "Effect of 'bridge leers' on the rate of temperature in Fourcault machines," by S. V. Rodin; (16) "Rapid method for analyzing glass," by O. V. Krasnovskiĭ. M.V.Kondoidy

PATENTS

Apparatus for:

Drawing glass tubes. N. V. Mij. tot Beheer en Exploitatie van Octrooien and Leopoldo Sanchez-Vello. Ger. 597,272, May 19, 1934. (*C.A.*)

Flowing molten glass. Forges et ateliers de constructions électriques de Jeumont. Fr. 763,039, April 23, 1934. (*C.A.*)

Inspecting glass. D. H. Boggs (Pittsburgh Plate Glass Co.). U. S. 1,974,598, Sept. 25, 1934.

Making glassware. K. E. Peiler (Hartford-Empire Co.). U. S. 1,975,050, Sept. 25, 1934.

Regulating the height of the surface of fused glass in the glassmelting furnace. Hachirô Shimada. Japan. 101,419, June 8, 1933. The height of the fused glass is electrically indicated to show the amount of the material to be charged. (*C.A.*)

Severing sheet glass. William Owen (Pittsburgh Plate Glass Co.). U. S. 1,973,723, Sept. 18, 1934.

Treating sheet glass. C. H. Wright and B. H. Weekley (Libbey-Owens-Ford Glass Co.). U. S. 1,972,965, Sept. 11, 1934.

Withdrawing glass from the furnace. Soc. anon. d'études et de constructions d'appareils mécaniques pour la verrerie. Fr. 43,232, April 6, 1934; addition to 751,357, "Glass," *Ceram. Abs.*, 13 [10], 259 (1934). (*C.A.*)

Casting glass rollers and other massive glass articles. Patent-Treuhand-Ges. für elek. Glühlampen m.b.H. (Bruno Kindt, inventor). Ger. 597,273, May 19, 1934. Molten glass is poured into a previously made hollow glass article having the shape of the article to be made. The hollow article should be as free from bubbles as possible. (*C.A.*)

Control of movements of units of glass-forming machines. Europäischer Verband der Flaschenfabriken G.m.b.H. Ger. 591,133, Dec. 28, 1933. The various individual movements of the mold units such as opening, or lifting, are capable of independent adjustment without affecting each other during the rotation of the machine. (*J.S.G.T.*)

Device for drawing endless glass band. N. V. Hollandsche Mij. voor de Vervaardiging van Glas. Ger. 595,683, April 16, 1934, and Ger. 596,764, May 12, 1934. (*C.A.*)

Device for use in cutting glass. William Owen (Pittsburgh Plate Glass Co.). U. S. 1,974,627, Sept. 25, 1934.

Drift control for leers and drift responsive means there-

for. H. A. WADMAN AND H. W. MCINTOSH (Hartford-Empire Co.). U. S. 1,973,452, Sept. 11, 1934.

Electric furnace for fusing glass. AKT.-GES. BROWN, BOVERI & CIE. Fr. 763,294, April 26, 1934. (*C.A.*)

Glass. JENAER GLASWERK SCHOTT & GEN. Ger. 596,513, May 3, 1934. An optical glass of μ above 1.6 contains SiO_2, at least 10% of an alkaline-earth oxide, up to 20% TiO_2, and other uni-, bi-, or tri-valent oxides. The glass may contain 35% of a bivalent oxide and Sb_2O_3. Examples are given of glasses containing SiO_2, BiO_3, Al_2O_3, Na_2O, CuO, BaO, ZnO, PbO, Sb_2O_3, TiO_2, and As_2O_3. (*C.A.*)

Glass for alkali-metal-vapor lamps. CORNING GLASS WORKS. Fr. 764,448, May 22, 1934. The glass of the lamps contains SiO_2 55 to 77, B_2O_3 10 to 25, and alkali metal oxide with or without alkaline earth 10 to 25%. (*C.A.*)

Glass for electric lamps. DEGEA A.-G. (Auergesellschaft). Fr. 764,088, May 14, 1934. Glass for artificial lighting is tinted with Nd oxide. (*C.A.*)

Glass for mercury-vapor lamps. PATENT-TREUHAND-GES. FÜR ELEKTRISCHE GLÜHLAMPEN M.B.H. (Rudolf Schmidt, inventor). Ger. 598,325, June 8, 1934. Use is made of borosilicate glass containing B_2O_3 4 to 18, alkaline earth oxides 3 to 10, and alkali oxides 15 to 22%. More than two-thirds of the alkali oxide content must be K_2O. A typical glass contains SiO_2 68, B_2O_3 8, K_2O 13, Na_2O 3, CaO 5, and Al_2O_3 3%. (*C.A.*)

Glassmelting furnace. P. L. GEER (Amco, Inc.). U. S. 1,973,688, Sept. 11, 1934.

Glass molding machine. R. G. ALLEN (Owens-Illinois Glass Co.). U. S. 1,974,841, Sept. 25, 1934.

Glass pipe. D. E. GRAY (Corning Glass Works). U. S. 1,975,269, Oct. 2, 1934.

Glass transparent to ultra-violet rays. TOKYO DENKI K. K. (Kitsuzô Fuwa and Fuzio Suzuki, inventors). Japan. 101,817, July 1, 1933 NaF (1 to 5%) and 1 to 5% NH_4 oxalate are added to ordinary glass material. (*C.A.*)

Joining ceramic materials to glass. PORZELLANFABRIK KAHLA. Fr. 764,273, May 17, 1934. A glass is used with a thermal expansion coefficient lower than that of the ceramic materials. Thus, pure Mg silicates such as Calit or Calan may be used for the ceramic materials to be fused to ordinary glass. (*C.A.*)

Laminated glass and process of making. P. R. MORRIS (Duplate Corp.). U. S. 1,974,624, Sept. 25, 1934. A laminated plate comprises a pair of glass sheets cemented to the opposite sides of a sheet of dibutyl phthalate pyroxylin plastic by a phenol gelatin condensation product.

Lens grinding machine. JOSEPH DI SANTO. U. S. 1,973,527, Sept. 11, 1934. J. S. GALESKI. U. S. 1,974,607, Sept. 25, 1934.

Machine of Schiller type for blowing large bottles. BORNKESSEL BRENNER UND GLASMASCHINEN G.M.B.H. Ger. 581,094, July 6, 1933. The mold halves are pivoted on an axis disposed behind the supporting pillar so that the latter is between the axis and the center line through the mold cavity. (*J.S.G.T.*)

Manufacture of tubular glass article. ALFRED HOFMANN AND VICTOR ANDERSON (Alfred Hofmann & Co.). U. S. 1,974,399, Sept. 18, 1934.

Method and apparatus for annealing glassware. H. A. WADMAN (Hartford-Empire Co.). U. S. 1,974,058, Sept. 18, 1934.

Method and apparatus for forming glassware. E. H. LORENZ (Hartford-Empire Co.). U. S. 1,974,824, Sept. 25, 1934.

Method and apparatus for the manufacture of hollow glassware. HARTFORD-EMPIRE CO. Brit. 415,634, Sept. 5, 1934.

Method and apparatus for melting glass. P. L. GEER, H. A. MOORE, AND W. A. MORTON (Amco, Inc.). U. S. 1,973,689, Sept. 11, 1934.

Means for and method of separating glass sheets. A. E. SPINASSE. U. S. 1,973,546, Sept. 11, 1934.

Method of fining borosilicate glasses and products produced thereby. R. HADDAN (Corning Glass Works). Brit. 416,473, Sept. 26, 1934.

Method of producing a luminescent glass. M. FISCHER, M. FISCHER, AND H. FISCHER (Glaswerk G. Fischer). Brit. 415,536, Sept. 5, 1934.

Motion of feeder plunger. GLASWERKE RUHR A.-G. Ger. 590,909, Dec. 21, 1933. The plunger descends through at least part of its stroke with a velocity greater than that of free fall of the glass gob. (*J.S.G.T.*)

Objective. LUDWIG BERTELE (Zeiss Ikon A.-G.). U. S. 1,975,677 and 1,975,678, Oct. 2, 1934.

Optical lenses and similar devices. P. K. DE GOOREYND AND A. W. KINGSTON. Brit. 416,398, Sept. 26, 1934.

Plate glass surfacing table. JACOB SODERBERG (Pittsburgh Plate Glass Co.). U. S. 1,973,733, Sept. 18, 1934.

Prevention of air bubbles in glass. LEOPOLDO SANCHEZ-VELLO (N. V. Mij. tot Beheer en Exploitatie van Octrooien). U. S. 1,975,737, Oct. 2, 1934.

Processes for the manufacture of changeant or opalescent glass. NORBERT KREIDL (Glashüttenwerke vorm. J. Schreiber & Neffen). U. S. 1,975,397, Oct. 2, 1934.

Production of undercut seatings in bottle mouths. HALLESCHE PFÄNNERSCHAFT ABTG. DER MANSFELD A.-G. FÜR BERGBAU UND HÜTTENBETRIEB. Ger. 591,283, Dec. 28, 1933. (*J.S.G.T.*)

Safety glass. C. F. BOEHRINGER & SOEHNE G.M.B.H. Fr. 764,287, May 17, 1934. The intermediate layer is composed of gellified cellulose esters or ethers containing 150 parts of gellifying agent for 100 of cellulose derivative. The gellifying agent may be a polyglycerol ester of a lower fatty acid, mixed, if desired, with benzyl alcohol. (*C.A.*)

Safety glass. RHEINISCH-WESTFÄLISCHE-SPRENGSTOFF A.-G. Ger. 595,560, April 14, 1934. See Brit. 370,958, *Ceram. Abs.*, **11** [7], 410 (1932). (*C.A.*)

Solution for making duplex glass plates. A. BOSSE. Belg. 399,509, Dec. 30, 1933. A cellulose ester or ether and hydrocarbons are dissolved by warming with halogen-substitution products; when solution is complete, vegetable oils, glycerol, or other solvents are added. (*C.A.*)

Strengthening glassware by surface treatment. J. B. MURGATROYD (Hartford-Empire Co.). U. S. 1,973,501, Sept. 11, 1934.

Transfer mechanism. A. J. SMITH (Hartford-Empire Co.). U. S. 1,974,394, Sept. 18, 1934.

Structural Clay Products

Bituminous clays in the production of brick and their firing. P. THOR. *Ziegelwelt*, **65** [8], 76–77 (1934).—The effect of bitumen on the properties of clays and directions for firing brick from bituminous clays are briefly discussed. M.V.K.

Brick slabs for veneering work. ANON. *Brick Clay Rec.*, **85** [3], 83–86 (1934). Illustrated. E.J.V.

Brick stand the test. ANON. *Brit. Clayworker*, **43** [508], 132–33 (1934).—A review and summary of a report released by the British Building Research Station is given. See also "Sand-lime brick," *Ceram. Abs.*, **13** [10], 261 (1934). R.A.H.

Concrete sanitary sewer disintegrates after six years service. ANON. *Brick Clay Rec.*, **85** [3], 88–89 (1934).—In Tucson, Ariz., a concrete sewer failed completely after only six years of service. Illustrated. E.J.V.

Cutting clay shapes for special units. L. R. WHITAKER. *Brick Clay Rec.*, **85** [2], 62–64 (1934).—Simple methods by which plant operators can develop odd-shaped brick from architect's plans are discussed. These include use of a bow and wire for a cutting medium, dies or wooden boxes to produce profiles of shapes, and a drill press for cutting shapes made up of curved lines. Factors to be taken into consideration such as the maximum dimension a clay will follow, etc., are listed. Illustrated. E.J.V.

Final steps in making special shapes. L. R. WHITAKER. *Brick Clay Rec.*, **85** [3], 96 (1934).—Care in drying special shapes is stressed, as it is inadvisable to stack them too high for drying. They may be fired on top of the setting of the kiln, where there is little superimposed weight, in "boxes" lower in the kiln, or in tight-bolt setting still lower in the kiln. Although the firing process is not changed greater care is taken when special shapes are being fired and in drawing the kiln to properly sort out the special shapes. Methods of figuring prices to charge for special shapes are discussed. See preceding abstract and *Ceram. Abs.*, **13** [8], 209; [9], 237 (1934). E.J.V.

Philadelphia chooses paving brick for its cardinal traffic arteries. ANON. *Brick Clay Rec.*, **85** [3], 90–91 (1934).—The qualities of vitrified paving brick gained the contract for paving Chestnut and Walnut Streets. Illustrated. E.J.V.

Reinforced brick masonry structures. ANON. *Clay Prod. News*, **7** [9], 1 (1934).—Tests show that by various methods of reinforcing and through the use of different types of reinforcing rods the strength may be increased to 5 to 9½ times the design live load. M.C.S.

Work of a testing engineer in a brick plant. WALTER DAWIHL. *Tonind.-Ztg.*, **58** [51], 610–12 (1934).—The supervising duties of an engineer, especially concerning the testing of the transverse strength of brick, are described. M.V.K.

BULLETIN

Mechanical properties of brick and brickwork masonry. W. H. GLANVILLE AND P. W. BARNETT. *Dept. Sci. Ind. Research, Building Research, Special Rept.*, No. 22, 23 pp. (1934).—Data are given on various methods of testing individual brick. The most convenient method consists in testing flat between plywood sheets, with the frogs filled. No definite relationship exists between the strength of brick masonry and that of individual brick. Stress-strain curves and moduli of elasticity for brick piers and data on the effect of mortar strength on pier strength are given, with tabulated results on the physical properties of the various types tested mechanically. (*B.C.A.*)

PATENT

Brick lifter. SAMUEL POLIAKOFF (Canal Storage Co., Inc.). U. S. 1,974,891 and 1,974,892, Sept. 25, 1934.

Refractories

Acid-resistant ceramic ware and high-quality refractories from clays of Druzhkovka. P. P. BUDNIKOFF. *Ukrain. Chem. Jour.*, **8** [2], 260–66 (1934). S.I.P.

Aluminum from clay. A. A. YAKOVKIN. *Legkie Metallui*, No. 10–11, pp. 3–7 (1932); abstracted in *Chem. Zentr.*, **i**, 2482 (1934).—Researches in Russia have shown that the continuous treatment of clay with 50 or 56% HNO_3 in counter-current at about 100° is possible with either ceramic or metallic apparatus. The $Al(NO_3)_3$ solution obtained is freed from $Fe(NO_3)_3$ by adsorption with polishing red and filtering. $Al(NO_3)_3 \cdot 9H_2O$ is crystallized, yielding its water and then its HNO_3 on heating; for a complete decomposition, temperatures of 700 to 800° are necessary. Ti remains partly as undissolved TiO_2 and partly goes into solution as nitrate. The HNO_3 losses are estimated at about 2 or 3%. M.V.K.

Bauxite occurrence in the island of Amorgos. E. VADÁSZ. *Centr. Mineral. Geol.*, **A**, pp. 182–85 (1934).—The island is built up of limestone on the surface of which are layers of bauxite. The layers extend over about 5000 sq. m. with an estimated weight of 100,000 tons. Analyses gave 55.0 to 62.7% Al_2O_3. Of all the Grecian bauxites this is the most difficult from which to extract the Al_2O_3. Six hours' digestion in caustic soda at 10 atmospheres yielded only 30 to 39% Al_2O_3. The low yield may be due to a metamorphism of which evidences are observable in the accompanying limestone. (*C.A.*)

Brick bond for coke-oven walls. W. GOLLMER. *Glückauf*, **70** [33], 768–69 (1934).—A few new shapes of brick for building walls of coke ovens are described. These shapes were developed to give better strength to withstand gas pressures. M.H.

Chrome corundum. FRANK W. PRESTON. *Jour. Amer. Ceram. Soc.*, **17** [11], 356–57 (1934).

Comparison of methods for determining slagging resistance of refractory materials. A. A. KRUILOV. *Ogneuporui*, **1** [6–7], 31–36 (1933); abstracted in *Chem. Zentr.*, **i**, 2963 (1934).—Three methods for testing the slag resistance of refractories are compared with respect to their conformity with results in service. Miehr's method,

consisting in boring the refractory and melting slag in the boring, does not take into consideration the favorable effects of the surface of the brick and the action of the slag flow which greatly increases the chemical attack in practice. Turner's method, based on the action of K_2CO_3 + Na_2CO_3 melt on crushed brick, requires a complicated equipment but yields figures approaching practical results. The best results are obtained with Norton's method (*Jour. Amer. Ceram. Soc.*, 7 [8], 599–602 (1924)), based on the dripping of liquid slag on the surface of an inclined brick and determining the slag attack from the weight of the brick before and after the treatment. A method of procedure according to this method is developed for testing small brick samples (5 x 5 cm.). M.V.K.

Dry pressing grog brick from Borovichi clay. D. N. Polubovarinov, R. J. Popilski, and T. Ya. Chinilkina. *Ogneuporui*, 1 [6–7], 4–10 (1933); abstracted in *Chem. Zentr.*, i, 2961 (1934).—Attempts to dry-press grog brick from Borovichi clays of various kinds and compositions were successful. The brick had good mechanical properties and their shapes were stable on firing. M.V.K.

Effect of the lowered firing of grog on the properties of refractory materials. A. A. Vinogradov. *Ogneuporui*, 1 [6–7], 15–18 (1933); abstracted in *Chem. Zentr.*, i, 2962 (1934).—The effect of the firing temperature of grog used in refractory brick on the properties of these refractories was studied. Grog was fired at 400, 900, 1100, and 1350°C and mixed with clay in definite ratios; the refractories were prepared by wet-shaping; their firing temperature was 1350°C. It was found that a low temperature (900°) of grog firing yields a lower porosity in brick than a high firing temperature. The density of the brick and the shrinkage on firing are higher with a low-fired grog. The firing temperature of grog must be selected according to the use of the brick. M.V.K.

Effects of lime addition and of granulometric composition on the properties of Dinas brick. I. S. Kainarskiĭ. *Ogneuporui*, 1 [4], 10–15 (1933); abstracted in *Chem. Zentr.*, i, 2961 (1934).—Nine Dinas mixes of similar composition but various grain-size distribution and varying additions of lime (1 to 5%) were tested. It was found that the CaO content has a considerable effect on the color, density, and mechanical strength of the brick. The mechanical strength increases in linear dependence on the increased CaO content. The CaO content has no effect on the expansion, porosity, refractoriness, and resistance to pressure at high temperatures. The grain-size distribution is of special importance for the mechanical strength, expansion, porosity, density, and color, but has no effect on refractoriness and resistance to pressure at high temperatures. M.V.K.

Fused cyanite. P. S. Mamuikin and A. F. Ogarinov. *Ogneuporui*, 1 [6–7], 23–26 (1933); abstracted in *Chem. Zentr.*, i, 2961 (1934).—Attempts to fuse cyanite (47.6 SiO_2, 49.2 Al_2O_3 + TiO_2, 2.25 Fe_2O_3, 0.2 CaO, and 0.9% MgO) from the Urals are described; 10% clay was added to increase the alumina content. The melting was undertaken in an electric resistance furnace at a temperature of about 1850°C. The melting proceeded smoothly without white vaporization, chiefly consisting of SiO_2. The cooled samples showed a mullite structure and high temperature stability, but they had low resistance to temperature changes. However, the production of refractories in the manner described is possible in principle. To increase the alumina content, a part of the SiO_2 may be combined by the addition of Fe_2O_3 and coke (forming ferrosilicon). M.V.K.

Gaseous permeability of ceramic products at high temperatures. P. Bremond. *Céramique*, 37 [552], 53–57 (1934).—B. discusses and establishes gas laws of permeability and absorption and shows their relation to the proper choice of saggers. See also *Ceram. Abs.*, 13 [6], 151; [10], 275 (1934). M.H.B.

Granulometric composition of Dinas mixes. G. V. Kukolev. *Ogneuporui*, 1 [4], 4–10 (1933); abstracted in *Chem. Zentr.*, i, 2961 (1934).—The importance of the grain size and the distribution of grains in Dinas brick for the behavior of the product on firing and in practice is dealt with. Defects are discussed. M.V.K.

Heat of formation of SiC and the existence of siloxicon. Ronald Brunner. *Z. anorg. allgem. Chem.*, 217 [2], 157–60 (1934).—The heat of formation of SiC is redetermined. Some evidence of the existence of a third phase, possibly siloxicon, was obtained. L.T.B.

Insulating refractory. A. P. Green Fire Brick Co. *Blast Fur. Steel Plant*, 22 [9], 540 (1934).—The physical characteristics of G-25 are enumerated. E.J.V.

Mechanical properties of dry-pressed grog brick. V. G. Yakovlev. *Ogneuporui*, 1 [6–7], 11–15 (1934); abstracted in *Chem. Zentr.*, i, 2961–62 (1934).—The effect of clay and grog content, moisture, and pressure of dry-pressed fired grog brick was studied. An increased pressure increases the compressive strength in all brick. The pressure can not be more than 300 to 500 kg./sq. cm. because the brick breaks up into layers. The increase of the grog content with a constant water content lowers the compressive strength; the increase of the water content improves the latter. The best results were obtained in brick containing 80 to 85% finely ground clay, a low amount of grog of medium granulation (20 to 15%), and a moderate water content (10%). M.V.K.

Melting aluminum in reverberatory furnaces. E. T. Richards. *Chem.-Ztg.*, 58 [13], 135–36 (1934); abstracted in *Chim. & ind.*, 32 [1], 96 (1934); *Tonind.-Ztg.*, 58 [43], 522 (1934).—Details of the construction, including refractories, and operation of reverberatory furnaces used for melting aluminum are given. M.V.K.

Navy simulative service test. Gregory L. Rogers. *Bull. Amer. Ceram. Soc.*, 13 [10], 262–64 (1934).

Needle heating surface for improving capacity of heat exchangers. Anon. *Chem. App.*, 21 [15], 148 (1934).—By arranging needle-like protrusions on the surface of a heater instead of the usual ribs, etc., the heating capacity was increased in the ratio 1:1.57. Needles are 40 mm. long with 8 mm. diameter tapering to 3 mm. at the end, and are spaced 14 mm. apart. Air-preheaters built in this manner were particularly economical up to 600°C. M.H.

Porosity lowered in grog ware. Beninga. *Tonind.-Ztg.*, 58 [54], 657–59 (1934); *Keram. Rund.*, 42 [36], 451–53 (1934).—The determination of granular composition by means of sifting or from sifted grain fractions and the effect of the granular composition on porosity are discussed. M.V.K.

Quartzites of the "Losovaya Balka." G. V. KUKOLEV AND G. B. TAUBIN. *Ogneuporui*, **1** [4], 15–23 (1933); abstracted in *Chem. Zentr.*, **i**, 2961 (1934).—Petrographic, physicochemical, and technological properties of quartzites and their working for the production of silica brick of high quality are discussed. M.V.K.

Recuperation in reverberatory furnaces. MOREL-D'ARLEUX. *Céramique*, **37** [550], 1–9 (1934).—M. discusses the theoretical and practical aspects of recuperation. M.H.B.

Recuperators of modern construction in reverberatory furnaces. F. EGOROV. *Vestnik Metalloprom.*, **13** [10], 48–51 (1933); abstracted in *Chim. & ind.*, **32** [1], 92 (1934).—Heat recuperators made of special ceramic materials resist high temperatures much better than those of cast iron, but they have other defects. It is impossible to make them air-tight in the joints. M.V.K.

Refractoriness of clay-quartz brick. D. N. POLUBOYARINOV. *Ogneuporui*, **1** [5], 23–27 (1933); abstracted in *Chem. Zentr.*, **i**, 3251 (1934).—The softening temperature of clay-quartz brick is greatly affected by the grain size of the quartz. Decreasing the grain size of quartz from 1 mm. to 0.2 mm. slightly lessens the refractoriness of the brick; if the grain size is less than 0.1 mm., the softening temperature is lowered to cone 4. M.V.K.

Refractoriness of sillimanite. O. REBUFFAT. *Giorn. chim. ind. applicata*, **16** [7], 334–35 (1934).—The refractory properties of pure sillimanite are superior to those of mixtures with mullite and Al_2O_3. Its softening point is higher and its expansion smaller. Curves for different mixtures as a function of temperature are given. Under a pressure of 2 kg./cm.², sillimanite begins to soften at 1730°C and melts at 1870°C. M.H.

Refractory and alkali-stable ceramic materials. WILHELM MIEHR. *Chem.-Ztg.*, **58** [49], 497–501 (1934); abstracted in *Tonind.-Ztg.*, **58** [57], 696 (1934).—A concise review is given of the various methods of manufacture of refractory and acid- and alkali-stable products. A table showing the properties of various materials is given. The manufacture of new products and new methods of working are described with references to the results obtained. At present coarse ceramic materials are worked in the following ways: (1) transformation of clay materials into mullite with the least possible amount of silicate glass; (2) transformation of quartz-containing materials into tridymite or quartz glass; (3) conversion of alumina into sintered or crystallized corundum; (4) conversion of magnesite into periclase; (5) transformation of alumina and magnesite into spinel; and (6) conversion of alumina, magnesite, and chromite into siemensite-spinel. M.V.K.

Refractory materials for blast furnaces. ALFRED B. SEARLE. *Blast Fur. Steel Plant*, **22** [9], 540–41 (1934); see also *Ceram. Abs.*, **13** [7], 183 (1934). E.J.V.

Refractory materials in modern boiler furnaces. JOHN WALKER. *Eng. Boiler House Rev.*, **47** [10], 700–702 (1934); abstracted in *Sprechsaal*, **67** [30], 450 (1934).—Results of practical observations on the effects of water-cooling and air-cooling are discussed. M.V.K.

Refractory products news at the Achema VII in Köln. PAUL DOLCH. *Chem.-Ztg.*, **58** [47], 478 (1934); abstracted in *Tonind.-Ztg.*, **58** [57], 696 (1934).—A short description is given of (1) slag-stable "Chromo-Dur brick," (2) "Cu-brick" used in blast and revolving furnaces, retorts, and generators (they are not affected by carbon monoxide and hydrocarbon), (3) magnesite brick from native materials, and (4) a new type of sillimanite brick which, because of its high porosity, insulates effectively. M.V.K.

Silicon carbide for working granite. A. V. CHARRIN. *Rev. mat. constr. trav. pub.*, No. 299, pp. 57–58*M* (1934).—The properties of silicon carbide and the production of silicon carbide abrasives and their use for polishing granite are discussed. M.V.K.

Studies of refractory minerals. No. 20. Sericite. ANON. *Refrac. Jour.*, **10** [6], 228 (1934).—The formation and properties of sericite are described. **No. 21.** *Ibid.*, **10** [7], 321 (1934). **No. 22. Dumortierite.** *Ibid.*, **10** [8], 370 (1934).—The origin, composition, and uses of dumortierite as a ceramic raw material are discussed. M.C.S.

Testing of and a specification for glasshouse pot clays. J. H. PARTRIDGE. *Jour. Soc. Glass Tech.*, **18** [70], 128–42 (1934).—The causes of failure of glassmelting pots are enumerated and methods for assessing the resistance of clay mixtures to specific types of failure are briefly described. The behavior of pots in service is correlated with the results of the laboratory tests enabling a specification to be compiled based upon certain physical properties of the clay rather than upon its chemical composition. One of the most tedious tests in this connection is that of determining the limiting creep strength of the clays, and new apparatus is described for this purpose. It is shown that the limiting creep strength at high temperatures is affected most markedly by an increase in temperature and by the proportion and character of the grog particles. There appears to be no obvious relationship between the limiting creep strength and either the ultimate strength or the temperature at which rapid extension occurs on the temperature-extension curve determined at constant load.

Thermal conductivity of diatomite at moderately high temperatures. C. D. NIVEN. *Can. Jour. Research*, **11** [3], 249–53 (1934).—Various kinds of diatomite brick were examined to ascertain how the thermal conductivity of diatomite found at Quesnel, British Columbia, compared with conductivities of other diatomites. Measuring thermal conductivity with accuracy above 1500°F is difficult; this necessitated limiting the investigation between atmospheric temperature and 1500°F. Excepting a brick of natural Calif. diatomite, the Quesnel brick was the best thermal insulator of the samples tested. E.J.V.

Thermal expansion of refractory brick for boiler furnaces. I-II. SOKICHI KAWAGUCHI. *Jour. Soc. Chem. Ind.* [Japan], **37** [7], 407–12*B* (1934).—An apparatus for measuring the contraction and thermal expansion of various refractories, such as agalmatolite, grog, mullite, and silicon carbide brick, up to 1400°C is described. It was found that (1) agalmatolite brick show a characteristic thermal expansion at 550° (quartz effect) and become soft, fissure, and deform between 1100 and 1200°; (2) grog brick expand rectilinearly up to 1300 or 1400°; at higher temperatures they contract; and (3) mullite and silicon carbide brick also expand rectilinearly but do not soften, even at 1400°C. M.V.K.

Ural bauxites and their working by the Bayer method. D. S. Abramson and A. V. Pavlov. *Legkie Metallui*, No. 6, pp. 8–18 (1933); abstracted in *Chem. Zentr.*, I, 2570 (1934).—A detailed discussion is given of the bauxite deposits of the Urals and their application after a partial removal of SiO_2 and P_2O_5 according to the Bayer method. M.V.K.

BOOK REVIEW

Refractories in Metallurgy (Ogneuporui v Metallurgii). Gosudarst. Nauch.-Tekh. Izdatelstvo Chernoĭ i Tzvetnoĭ Metallurgii, Moscow, 1933. 256 pp. Illustrated by diagrams. Price 3 R 20 k. The book includes (1) "Physicochemical conditions of producing refractory materials," by A. A. Baikov; (2) "Refractoriness," by E. Keler; (3) "Deformation of refractory products under load at high temperature," by E. Keler; (4) "Refractory materials for coke ovens," by R. L. Pevzner; (5) "Refractory materials for blast furnaces," by A. A. Popov; (6) "Using black Dinas in Martin furnaces," by P. P. Budnikoff and N. S. Smelyanskiĭ; (7) "Magnesite and chrome-magnesite brick," by Kilesso and Chekassinov; (8) "Effect of iron oxide on the properties of magnesite brick," by F. G. Blinov; (9) "Refractory plugs and vessels for casting ladles," by P. P. Budnikoff and S. P. Loginov; (10) "Plugs and vessels for casting ladles from Ural raw materials," by V. H. Shvetzov; (11) "Refractory ware in metallurgy," by P. P. Budnikoff and S. P. Loginov; (12) "Refractory linings and cements," by K. A. Karayanopulo. M.V.Kondoidy

BULLETIN

Thermal insulation. Anon. *Nat. Bur. Stand. Letter Circ.*, No. 421, 5 pp. Free. This letter circular has been prepared to serve as a reply to numerous requests for information on thermal insulation and allied subjects. Bibliography. R.A.H.

PATENTS

Glazed refractory articles and method of making. R. C. Benner and H. N. Baumann, Jr. U. S. 1,975,069, Oct. 2, 1934.

Manufacture of refractory brick, etc., from chrome ore. Elisabeth Lux (Koppers Co.). U. S. 1,973,907, Sept. 18, 1934. A method for manufacturing refractory brick, etc., from chrome ore comprises adding to between 90 and 60% of reduced chrome ore of about 40% Cr_2O_3, between 10 and 40% of reduced metallurgical slag recovered as a waste product of a metallurgical process and consisting of not less than substantially 90% of magnesia and alumina and not more than 1% of silica, adding a liquid, molding the mass into shapes, and finally firing the shapes.

Molding refractory objects. Corning Glass Works. Ger. 595,983, April 25, 1934. (*C.A.*)

Observation holes for furnaces. Jointless Fire Brick Co., Ltd. (Plibrico Jointless Firebrick Co.). Brit. 416,159, Sept. 19, 1934.

Refractory brick and process of making. E. M. Harvey and J. A. Boren. U. S. 1,973,434, Sept. 11, 1934.

Refractory compositions. Veitscher Magnesitwerke-A.-G. Austrian 137,672, May 25, 1934. Calcined magnesite containing little or no CaO is mixed with a Cr ore, a small proportion of finely ground clay, and a concentrated solution of an acid electrolyte, *e.g.*, $NaHSO_4$. The mixture is then molded under pressure and dried at 50 to 200°. Suitable proportions are calcined magnesite 75 to 86, Cr ore 10 to 20, clay 2 to 5, and $NaHSO_4$ 2 to 4%. (*C.A.*)

Refractory material. Austenal Laboratories, Inc. Fr. 763,464, May 1, 1934. A refractory paste which hardens, for making molds used in dental technique, is made by acidifying an organic silicate such as tetraethyl, tetrabutyl, methyl, or diglycol silicate to produce a spontaneous growth of the colloidal particles of SiO_2 and mixing the material obtained with a refractory substance such as SiO_2 or Al_2O_3. The hardening may be accelerated by the presence of MgO or by heating to 110 to 115°. (*C.A.*)

Refractory materials. Erwin Herrmann. Ger. 598,-551, June 13, 1934. A mixture of fireproof clay and limestone is given an addition of Fe_2O_3 or MnO and SiO_2 and sintered to form a fireproof cement. (*C.A.*)

Process for producing molded bodies from practically pure aluminium oxide. L. Mellersh-Jackson (Siemens & Halske Akt.-Ges.). Brit. 415,579, Sept. 5, 1934.

Terra Cotta

Shaping stoneware. W. Schuen. *Keram. Rund.*, **42** [16], 195–97; [17], 208–11 (1934).—Excerpts from a book, Manufacture of Stoneware Pipes, by S. are given. M.V.K.

Stoneware for the chemical industries. P. P. Budnikoff and S. A. Gicharevitsch. *Chem.-Ztg.*, **57** [91], 903–904 (1933).—Various South Russian clays can be used separately or with thinning or fluorspar additions in the manufacture of stoneware for the chemical industry. Adding artificially thinned clay to stoneware mixes permits reducing the amount of thinning agent to a minimum. This method promotes the formation of a more dense structure of the body with a normal shrinkage and a comparatively low firing temperature. It is necessary to grind and mix the components when they are moist to obtain stoneware of high quality; grinding fineness (thinning and fluorspar additions) may not exceed 900 mesh/sq. cm. For special ware, porcelain production methods should be used and the grinding fineness must be 4900 mesh/sq. cm. Ware of higher acid-stability are obtained when using the casting method than with plastic molding. M.V.K.

Stoneware conduit manufacture. Albion Clay Co., Ltd. *Elec. Rev.*, **115** [2960], 205–206 (1934).—The manufacture of a self-aligning multiple-way stoneware conduit is described. The ware is formed by extrusion and is salt glazed. A bituminous mixture sealing the joints forms the self-aligning feature. A special gas-tight patented joint in the form of a plug or removal flange is also supplied. Illustrated. J.L.G.

Various possibilities for using dunite. Carl Hein-

RICH PETERS. *Feuerungstechnik*, **22** [8], 97 (1934).—Dunite, a granular rock consisting of ferro-manganese and chrome iron ore, is found in the Ural mountains. Dunite approaches talc in chemical composition but differs from it because of an admixture of chrome and an iron content (9%). Its melting point is about 1600°C. Experiments showed that dunite is suitable for the manufacture of ceramic ware for technical purposes, *i.e.*, electrotechnical ware and ware requiring thermal resistance (pipes, plates, etc., and chemical apparatus). Dunite can also replace talc in the production of enamel cements. M.V.K.

BOOK REVIEW

Ceramic Radiators. B. YA. ZHUKOVSKY. Ukrainian State Pub. House, Light Ind., Kharkov, 1934. 56 pp., 29 illustrations. Price 0.75 R. In 1931 the Ukrainian Sci. Research Institute of Building Materials of Mineral Origin (Kiev), working on the problem of replacing metals in construction by ceramic ware, suggested using ceramic radiators in central heating systems instead of metallic radiators. The first 5000 ceramic radiators were manufactured on plant scale in 1931 and were used to heat plants during 1931 and 1932 with satisfactory results. S.I.PEREKAL

PATENT

Method and apparatus for forming tile. T. F. MOONEY (Ludowici-Celadon Co.). U. S. 1,973,092, Sept. 11, 1934.

White Wares

Buyer must be a statistician, economist, teacher, and psychologist to understand the customer's viewpoint. J. W. WINGATE. *Crockery & Glass Jour.*, **115** [2], 13 (1934).—Dealers in pottery, china, and glass must have a thorough knowledge of their ware and of the customer's desires, likes, and dislikes. A survey of the shoppers in a china and glass shop showed that 62% were interested chiefly in the workmanship and beauty of the ware, 14% put price first, and only 2% required novelty or newness. The methods of displaying china and glassware have much to do with successful marketing. M.C.S.

Constitution of porcelain. LEON FRANCQ. *Verre & Silicates Ind.*, **5** [15], 278–82; [16], 297–304 (1934).—F. discusses (1) the classification of porcelain, (2) its physicochemical constitution, and (3) its properties. Tables, diagrams, and bibliography are given. See also *Ceram. Abs.*, **13** [2], 43 (1934). M.V.K.

High-frequency insulating materials. H. HANDREK. *Hochfrequenztechnik & Elektroakustik*, **43** [3], 73–75 (1934); abstracted in *Physik. Ber.*, **15** [13], 1063 (1934).—New magnesium-silicate materials, Calit, Calan (*Ceram. Abs.*, **12** [9], 334 (1933)), Frequentite (*ibid.*, **13** [8], 215 (1934)), Frequenta, and Condensa, are described which have a small loss for short and ultra-short waves and a high dielectric constant. M.H.

High-voltage (porcelain) insulators. W. A. SMITH AND J. T. LUSIGNAN. *Elec. Eng.*, **53**, 969–73 (1934).—A comprehensive description of laboratory equipment required for adequate testing of insulators is given. Methods of testing are sketched. (*C.A.*)

Metallic oxide porcelain. F. DOBROVSKY. *Keram. Rund.*, **42** [12], 147–49 (1934).—The production of oxidized metal (Al) layers on earthen porcelain is described in detail. Finely distributed aluminum or a suitable Al alloy is applied by means of a spray gun. A thin (0.001 to 0.1 mm.) alumina layer which adheres solidly and gives a great resistance to the surface is obtained by anodic oxidation. This surface takes organic pigments well after having left the oxidation bath; the color is solidly combined with the surface. M.V.K.

Recent developments in (porcelain) suspension insulators. G. M. BARROW. *Elec. Eng.*, **53**, 867–70 (1934).—Illustrated. (*C.A.*)

Selection and performance of (porcelain) suspension insulators. PHILIP SPORN, E. L. PETERSON, AND V. A. MULFORD. *Elec. Eng.*, **53**, 936–42 (1934). (*C.A.*)

Standard Sanitary adds new pottery to its Canadian plant. ANON. *Ceram. Ind.*, **23** [4], 195–96 (1934).—Illustrated. E.J.V.

PATENTS

Ceramic materials. ROBERT BOSCH A.-G. Fr. 763,578, May 3, 1934. Ceramic materials, particularly for electric insulators, are made from highly refractory substances such as silicates, oxides or refractory carbides, and an agglutinant composed of substances of the nature of natural zeolites and artificial permutites. (*C.A.*)

Ceramic objects. ANDREW MALINOVSZKY. Ger. 595,643, April 18, 1934. A mixture of Mg silicates and glaze is molded, dried, heated to 900 to 1200° for not more than 30 min., removed from the hot zone, sprinkled with glaze, and then returned to the hot zone for not more than 10 min. The mixture may consist of SiO_2 40 to 70, Al_2O_3 2 to 12, MgO 15 to 50, CaO 5 to 8, PbO_2 1 to 6, and Na_2O 2 to 6%. (*C.A.*)

Ceramic objects. KARL SCHINDHELM. Ger. 596,501, May 4, 1934. A method of introducing metal cones, etc., into ceramic insulators by fusing the metal during firing of the insulator is described. (*C.A.*)

Insulator. W. W. SHAVER (Corning Glass Works). U. S. 1,975,297, Oct. 2, 1934.

Insulating materials. SIEMENS & HALSKE A.-G. Fr. 764,024, May 14, 1934. Dense materials suitable for electric insulators are made from MgO or BeO by adding to the calcined oxide a small amount of another nonplastic metal oxide, *e.g.*, Al_2O_3, or BeO is added to MgO or Al_2O_3 or MgO is added to BeO (1 mol. of added oxide to 10 to 30 mol. of principal oxide) and by agglutinating much below the melting point of the principal oxide. (*C.A.*)

Insulator. M. H. HUNT (Westinghouse Electric & Mfg. Co.). U. S. 1,973,076, Sept. 11, 1934. In combination, an inorganic dielectric member, a fired silicate-glaze coating thereon, and a fired high-resistance surface coating over the first coating comprises a mixture of a sili-

cate and a metallic glaze, the coatings being mechanically integral.

Method of applying a conducting coating on insulators. K. A. HAWLEY (Locke Insulator Corp.). U. S. 1,975,576, Oct. 2, 1934.

Porcelain. JUN'ICHI ISOBE. Japan. 101.239, May 22, 1933. The mechanical and electric nature of a porcelain is improved by mixing with the ordinary raw material more than 0.1% S. (*C.A.*)

Water closet. F. C. KRUSE. U. S. 1,973,349, Sept. 11, 1934. O. LUNDBERG. Brit. 415,960 Sept. 12, 1934.

Equipment and Apparatus

Apparatus for measuring thermal flow at high temperature. E. SCHMIDT AND J. WERNEBURG. *Z. Ver. deut. Ing.*, **78** [11], 343–46 (1934); abstracted in *Chim. & ind.*, **32** [2], 320 (1934).—This apparatus, composed of a perforated ceramic plate 0.9 cm. thick in the interior of which thermoelectric couples are attached, measures heat losses through the walls of industrial furnaces and the conductivity of refractory materials in service. It can be used for temperatures up to 600° and in exceptional cases up to 1000°. Details are given. M.V.K.

Apparatus for rapid investigation of sand, earth, and finely ground rocks for their content in mineralizers. PAUL DOLCH. *Chem.-Ztg.*, **58** [47], 480 (1934); abstracted in *Tonind.-Ztg.*, **58** [57], 696 (1934).—An elutriating apparatus of special construction is described. M.V.K.

Automatic dipping machine handles all kinds of pottery. F. H. SEBRING, JR. *Ceram. Ind.*, **23** [4], 197–98 (1934).—On a conveyer-type machine ware is dipped and spun at the same time to give a smooth coating of glaze and is passed under a hot-air duct to dry. Details are given. Illustrated. E.J.V.

Brick and tile machinery. I–IV. J. V. BRITTAIN. *Mech. World*, **96** [2484], 119–21; [2485], 149–50; [2486], 171–72; [2487], 202–204 (1934).—Illustrated. E.J.V.

Decrease in density of quartz on pulverizing. G. TAMMANN AND G. MORITZ. *Z. anorg. allgem. Chem.*, **218** [1], 267–72 (1934).—On pulverizing quartz the density decreases about 10%. Cristobalite and quartz glass show an increase of about 2% on pulverization. L.T.B.

Drying china clay, a new system. R. J. VARCOE. *Pottery Gaz.*, **59** [688], 1236–37 (1934).—A new drying system has been installed at the Greensplat China Clays Dry at Trenance, Cornwall. V. found that contact and conduction are the principal factors in drying, rather than heat. Saturated steam in the tubes proved a much quicker drying agent than dry steam and low-pressure saturated steam was found more penetrating than high pressure. Illustrated. See also *Ceram. Abs.*, **13** [11], 298 (1934). E.J.V.

Electrical indicator for viscosity measurements. E. J. HARRIS. *Ind. Chemist*, **10**, 139 (1934).—Details of construction, with two diagrams of circuits, are given of an electrical visual indicator for use in connection with the falling-sphere method of viscosity measurement, particularly for opaque liquids. The spheres are steel of $^1/_{16}$ in. diameter, but for very viscous liquids (η = 10 poises) $^1/_8$-in. balls are recommended. It is claimed for this visual method that the results are less dependent on the position of the observer than in the aural electrical method. H.H.S.

Handling air in the ceramic industry. R. R. ROBINSON. *Bull. Amer. Ceram. Soc.*, **13** [10], 266–70 (1934).

Photoelectric temperature controller. B. LANGE AND E. VOOS. *Z. tech. Physik*, **15** [8], 323–36 (1934).—A temperature controller for electric furnaces, thermostats, etc., is presented giving high speed controlling action. The accuracy amounts to ±0.17°C at temperatures above 1000°C. The controller is equipped with a compensation circuit including a mirror galvanometer, a new type of selenium resistance cell, and a thyratron. The controller may also be used for precision measurements of temperature. W.M.C.

Pyrometer designed by French physicist. ANON. *Gas Age-Rec.*, **74** [12], 250 (1934).—The Chevenard pyrometer uses the difference in expansion of a rod of Pyros and the fused silica tube containing the Pyros rod. Pyros is an alloy withstanding repeated cycles of heating to 2012°F and cooling without showing any deleterious effect. Illustrated. E.J.V.

Separation and precipitation of dusty materials by the van Tongeren process. W. REERINK. *Glückauf*, **70** [33], 764–68 (1934).—Dusts are removed from gases by a main blower. From here a partial current of the gas with the accumulated dust is led into an auxiliary blower where final removal is effected. The cleaned gas from this blower combines with the clean gas stream from the main blower. M.H.

Thermal insulation with Alfol aluminium foil. A. MAINELLI. *Allumnio*, **3**, 25–29 (1934); abstracted in *Chem. Zentr.*, **i**, 3104 (1934).—A description of the method, its characteristics, advantages, and application are given. M.V.K.

Thermoelements at high temperatures. A. SCHULZE. *Z. Ver. deut. Ing.*, **77** [46], 1241–42 (1933).—The report outlines a series of metals and alloys which may be used as thermoelements for measuring temperatures from 1000 to 2000°C. Charts are included showing the electrical effects obtained when combinations of the metals and alloys are combined as thermoelements. L.T.B.

Ware checked, blistered, warped; solved the trouble in the drier. ERNEST W. KNAPP. *Brick Clay Rec.*, **85** [3], 92–93 (1934).—In drying special shapes the clay was found to be sensitive to sudden temperature changes. Cracks and checks developed. Before entering the drier the ware was gradually warmed in a vestibule added to the drier, and by carefully controlling the humidity in the drier, the trouble was overcome. Other valuable changes in the drier construction are described. E.J.V.

PATENTS

Apparatus for fractionating kaolin, etc., by flotation.

WILLY HERTZSCH. Ger. 575,465, May 17, 1934. (*C.A.*)

Apparatus for projecting molten pulverized bodies. F. P. C. BENOIT. Brit. 416,452, Sept. 26, 1934.

Clay pin drying and cutting machine. W. W. IRWIN (Potters Supply Co.). U. S. 1,975,547, Oct. 2, 1934.

Machines for the manufacture of roofing tile, brick, paving slabs, and paving tile. W. G. POWEL. Brit. 416,035, Sept. 19, 1934.

Plastometer. W. L. SHEARER. U. S. 1,973,297, Sept. 11, 1934.

Power-driven machines for the production of roofing tile, floor tile, paving slabs, brick, blocks, etc. W. S. POWEL. Brit. 415,514, Sept. 5, 1934.

Vessel for carrying out reactions at high temperatures and pressures. I. G. FARBENIND. A.-G. (Ernest Hochschwender, inventor). Ger. 596,870, May 14, 1934. (*C.A.*)

Kilns, Furnaces, Fuels, and Combustion

Calculating combustion analysis in exact gas analyses. FRITZ SCHUSTER. *Feuerungstechnik*, **22** [7], 79 (1934).—The discussion is illustrated by examples. See also *Ceram. Abs.*, **13** [5], 129 (1934). M.V.K.

Ceramic ware firing symposium. JAMES T. ROBSON, ELLIS LOVEJOY, AND W. D. RICHARDSON. *Bull. Amer. Ceram. Soc.*, **13** [10], 276–80 (1934).

Combustion of solid fuel in industrial furnaces. A. JAESCHKE. *Emailletech. Monats-Blatter*, **10** [7], 79 (1934).—A discussion is given. M.V.K.

Electric behavior of three-phase arc furnaces. P. GOURDON. *Aciers spéciaux*, **9** [104], 115–24 (1934).—Principles of operation of 3-phase arc furnaces are explained and nomograms are developed from which characteristic operating data, such as output, power factor, and current, can be taken. M.H.

Fuel oil, its types, properties, and specifications. ANON. *Glass Ind.*, **15** [9], 213–14 (1934).—Distillate oils, residual oils, and blended oils are classed as fuel oil. The important properties of oil fuels for industrial use are (1) specific gravity, (2) heating value, (3) flash point, (4) pour point, (5) viscosity, (6) water and sediment, and (7) sulfur content. Fuel oil is generally sold on a volume basis. The heating value of fuel oils ranges between 18,000 and 20,000 B.t.u. per pound. E.J.V.

Heat values and heat losses through conduction and radiation. A. JAESCHKE. *Emailletech. Monats-Blätter*, **10** [9], 96–97 (1934).—A discussion is given. M.V.K.

Heating value. A. JAESCHKE. *Emailletech. Monats-Blätter*, **10** [8], 88–89 (1934).—The significance of heating values and their determination for solid fuel are discussed. M.V.K.

Rapid firing in continuous kilns. ANON. *Brit. Clayworker*, **43** [509], 157–61 (1934).—European practice in the construction of continuous kilns, particularly of the Hoffman and Zig-Zag types, is given. R.A.H.

Uniform thermal treatment. RALPH A. SHERMAN. *Bull. Amer. Ceram. Soc.*, **13** [10], 275–76 (1934).

Use of coal in an earthenware factory. M. FICHTER. *Céramique*, **37** [554], 105–10 (1934).—F. discusses the use of waste heat in a large earthenware factory and shows the economies effected. M.H.B.

PATENT

Recirculation control for kilns and furnaces. C. M. FRANCIS. U. S. 1,973,978, Sept. 18, 1934.

Geology

Beryllium (glucinum) minerals in Western Australia. H. BOWLEY. *Jour. Roy. Soc. Western Australia*, **18**, 83–84 (1932).—Helvite is a sulfo-silicate of Be, Mn, Fe, and Zn. Specimens found at Mt. Francisco, W. A., showed 13.9 BeO, 28.0 MnO, 15.8 FeO, 7.8 ZnO, 5.8 S, and 31.8% SiO_2. H.H.S.

Chemical and mineralogical composition of clays and their fusing point. A. H. B. CROSS. *Claycraft*, **6** [8], 259–61 (1933); abstracted in *Bldg. Sci. Abs.*, **6**, No. 11; *Rev. mat. constr. trav. pub.*, No. 296, p. 97*B* (1934). M.V.K.

Clays and feldspars of Manitoba. G. M. HUTT AND F. V. SIEBERT. *Clay Prod. News*, **7** [8], 1 (1934).—In the Province of Manitoba there are extensive deposits of surface clay suitable for common brick and shale for red dry-press brick, fireproofing, and sewer pipe. Bentonite and bentonite-like clays are reported available. There are also considerable amounts of microcline and orthoclase feldspar. M.C.S.

Feldspar. VIELHABER. *Emailwaren-Ind.*, **11** [34], 281–84 (1934).—V. discusses the composition of various types of German and Scandinavian feldspars and their suitability for enameling. Analyses are given. M.V.K.

Feldspars and the kaolinization of feldspar. M. HÖLLENWEGER AND H. RUMPELT. *Z. tech. Physik*, **15** [8] 318–22 (1934).—The phase diagram of potassium feldspars was determined from the melting temperatures Compounds and solutions of the system are discussed. Theoretical and experimental data show a good agreement. The solubility curve of potassium oxide shows a similar trend to that of the phase diagram. The solubility of compounds is small, and that of alkali increases with an increasing amount of foreign molecules. The kaolinization of feldspar is explained by thermodynamic considerations. The influence of size and shape of the kaolin particles is discussed. W.M.C.

Pegmatite: a gangue of usable minerals. VICTOR CHARRIN. *Chim. & ind.*, **32** [2], 476–78 (1934).—Various kinds of pegmatite, its use (including ceramics), minerals included in pegmatites (such as rutile, apatite, tourmaline, zirconium, rare earths, etc.), and French deposits are briefly discussed. M.V.K.

Refractory clays of the Berlin deposits. A. D. FEDOSEEV. *Ogneuporui*, **1** [5], 36–41 (1933); abstracted in *Chem. Zentr.*, **i**, 3382 (1934).—From the mechanical and thermal viewpoints the refractory clays of the Berlin deposits (South Urals) are usable for grog brick and sagger

mixes of low grade. Their high Fe_2O_3 + TiO_2 (3.8 to 4.2%) content prevents their use in the glass industry and fine ceramics. M.V.K.

Size distribution in the clay fraction. J. G. Steele and Richard Bradfield. *Amer. Soil Survey Assn., Rept. 14th Ann. Meeting, Bull.*, **15**, 88–93 (1934).—The mechanical analysis of Ellsworth and Miami silt loams by horizons is reported. Good agreement is found between the method of dispersion by electrodialysis followed by saturation with NaOH and that by treatment with Na oxalate. (*C.A.*)

Tool for producing true cores of clay. Anon. *Engineering*, **138**, 23 (1934).—A special tool is described by means of which true cores of clay in its undisturbed condition and free from the effects of compression or distortion can be obtained. (*T.C.S.E.*)

Undescribed variety of flint clay. S. L. Galpin and J. P. Nölting, Jr. *Jour. Amer. Ceram. Soc.*, **17** [11], 357–59 (1934).

BOOK REVIEW

Minerals Yearbook, 1934. U. S. Bureau of Mines. 1154 pp. Price $1.75 from Supt. of Documents, Govt. Printing Office, Washington, D. C. The 1934 volume is larger than its immediate predecessor and incorporates many improvements based on constructive suggestions volunteered by engineers in the mineral industry. In addition to accurate official data on all commercially important minerals, there is a résumé of principal economic trends in mining, and chapters deal with progress in coal utilization, natural gas production, clay, feldspar, etc. Developments under the National Recovery Administration are reviewed in the commodity discussions. All statistical material is presented in concise summary tables and 106 graphs illustrate the principal trends in various branches of the mineral industry. R.A.Heindl

BULLETINS

Geophysical prospecting abstracts. Frederick W. Lee. *Bur. Mines Periodical Service Rept.*, GA 63. 10¢. See also *Ceram. Abs.*, **13** [10], 273 (1934). R.A.H.

Talc and ground soapstone industry in 1933—advance summary. Anon. *Bur. Mines Mineral-Market Rept.*, MMS 293. 3 pp. R.A.H.

Chemistry and Physics

Action of quartz and alkali silicates on alkali carbonates. Carl Kröger and Ernst Fingas. *Z. anorg. allgem. Chem.*, **213** [1], 12–15 (1933).—The dissociation of lithium carbonate and the reaction of SiO_2 with $LiCO_3$ were studied in detail. Equilibrium was studied in the system K_2O–SiO_2–CO_2 and the heats of reaction were determined. A study was also made of the system Na_2O–SiO_2–CO_2 and the heats of formation of the sodium silicates were determined. L.T.B.

Analysis of cerium oxide in glasses. Anon. *Glass Ind.*, **15** [9], 212 (1934).—Cerium is a member of the third analytical group, being precipitated with Al, Fe, Ti, Zr, etc., by ammonium hydroxide. It can be separated from the members of the group and from other common metal bases by oxalic acid added to a slightly acid solution. If the cerium is known to be free of the other rare earths the oxalate precipitate may be dried, ignited at 1200°C, and weighed as the oxide (CeO_2). If other rare earths are present the oxalate precipitate and paper are ignited to the oxide with a blast lamp in a platinum crucible, and the oxides are covered with 10 cc. of concentrated H_2SO_4 until decomposition is complete, allowed to cool, and then carefully poured in 100 cc. of ice-cold water. If solution is not complete, 10 cc. more concentrated H_2SO_4 are added and the mixture is heated until a clear yellow solution is obtained. It is evaporated to 100 cc., 2 g. $(NH_4)_2SO_4$ and 1 g. sodium bismuthate are added, and the mixture is heated to boiling, cooled, filtered through a Gooch crucible, and washed with 100 to 150 cc. of 2% H_2SO_4. To this solution an excess of standard $N/40FeSO_4$ solution is added (color change yellow to colorless) and the excess is titrated back with standard $N/40$ permanganate solution. From the burette reading, the per cent of cerium is calculated so that 1Fe = 1Ce, 1 cc. $N/40$ $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$ = 0.004306 g. CeO_2 $\frac{172.25}{1000 \times 40}$. E.J.V.

Analysis of phosphosilicates. A. Lassieur. *Ann. chim. anal. chim. appl.*, **16**, 197 (1934).—If after separating PO_4''' from the metals by NH_4 molybdate, the molybdenum is removed from the filtrate (1) by evaporating with HCl and passing H_2S, a molybdenum-blue is formed if Fe is present. This is avoided if excess of aqueous NH_3 and $(NH_4)_2CO_3$ is added to (1) and the precipitate dissolved in HCl before passing H_2S. The traces of Ca and Mg in the filtrate are precipitated by ammonium oxalate and phosphate, respectively. If the P_2O_5 is less than 10% of the weight of Al_2O_3 + Fe_2O_3 the first is almost completely precipitated together with $Al(OH)_3$ and $Fe(OH)_3$, leaving Ca in solution. (*T.C.S.E.*)

Analysis of refractory clays and bauxite. Carl Heinrich Peters. *Feuerungstechnik*, **22** [8], 97 (1934).—The Russian Testing Office has developed several new methods for determining aluminum in refractory clays and bauxite and an analysis of clays and grog without using alkalis. M.V.K.

Analyzing industrial gases. H. Schwiedessen and G. Barth. *Arch. Eisenhüttenwesen*, **8**, 15–20 (1934).—The waste gas to be tested is first mixed with air, and the carbon dioxide is absorbed by means of a caustic potash solution. The remaining gas is burned over a platinum spiral, carbon dioxide is absorbed again, hydrogen is added, and the gas is burned again. Both qualitative and quantitative analyses may be carried out by this method. The main advantage claimed is that all oxygen will be absorbed, whereas in the ordinary methods oxygen may be determined as carbon dioxide. Gases containing hydrocarbons may be analyzed by the same method, provided a standardized chart is used for determining heating value of the gas, etc. W.M.C.

Calcium aluminates. II. Crystallization of calcium aluminate solutions at 40°C. G. Assarsson. *Z. anorg. allgem. Chem.*, **205** [3], 335–60 (1932). **III. Crystallization of calcium aluminate solutions at 90°C.** *Ibid.*,

214 [2], 158–66 (1933).—The calcium aluminate solutions used in the studies were made by the rapid solution of $CaO \cdot Al_2O_3$ in pure water. The course of crystallization was followed by analysis and microscopy. The residues identified consisted of $4CaO \cdot Al_2O_3 \cdot 13.5H_2O$, $3CaO \cdot Al_2O_3 \cdot 6H_2O$, $2CaO \cdot Al_2O_3 \cdot 9H_2O$, and aluminium hydroxide which was partly crystalline and partly in the gel form. The crystallization is similar to that which occurs at 40°C. For Part I see *Ceram. Abs.*, **11** [1], 61 (1932). L.T.B.

Change of the true specific gravity of kaolin on heating. T. NAKAI AND Y. FUKAMI. *Jour. Soc. Chem. Ind.* [Japan], **37** [8], 430–32*B* (1934).—A slight difference in the specific gravity was found in samples of kaolin heated to 400° due to various impurities. When heated to 500° or 600°, a great decrease in density was observed because of the decomposition of kaolinite into amorphous silica and alumina and water. Between 600° and 900°, the density gradually increased. At 900 to 1000°, amorphous alumina changed to crystalline γ-alumina showing a remarkable increase in the specific gravity. At 1100 to 1200°, γ-alumina and amorphous silica combined to form mullite, accompanied by an increase in specific gravity. Between 1200 to 1500°, the small quantities of impurities, such as alkalis, contained in the samples reacted with the silica and alumina, vitrifying them. Some difference in the specific gravity of the samples was also observed. M.V.K.

Collation of experimental data. XI. A. ALISON. *Glass*, **11** [6], 227 (1934).—A. describes the formulation and application of hyperbolic relationships. Descriptive charts and tables are included. **XII.** *Ibid.*, **11** [7], 264 (1934).—The use of Newton's interpolation formula is described and applications are presented. The interpolation formulas of Stirling and Gauss are discussed. **XIII.** *Ibid.*, **11** [8], 312 (1934).—Through the use of semi-logarithmic plotting, certain data may be represented more effectively and some results more clearly portrayed. Charts illustrating this type of plotting are included. For Parts IX–X see *Ceram. Abs.*, **13** [8], 218 (1934). M.C.S.

Colloidal solutions of silicic acid and their application in technology. I-II. R. GRIESSBACH. *Chem.-Ztg.*, **57** [26], 253–55; [28], 274–76 (1933).—A review of methods used for obtaining colloidal silicic acid solutions is given on the basis of scientific and technical literature. The properties of these solutions and their application in technology are discussed. Bibliography. M.V.K.

Composition of the calcine and analysis of compositions containing tin oxide. A. GRANGER. *Céramique*, **37** [550], 9–10 (1934).—Tin is quantitatively precipitated, free from lead, in a normal nitric acid solution by cupferron. M.H.B.

Constitution and process of crystallization of basic blast-furnace slag and their relationship with silicates of multi-compound systems. LEO KOCH. *Neues Jahrb. Mineral., Geol.*, **A67**, 401–25 (1933); abstracted in *Chem. Zentr.*, **i**, 2859 (1934). M.V.K.

Crystallization of amorphous silica: X-ray diffraction studies. F. P. DWYER AND D. P. MELLOR. *Jour. Roy. Soc. New South Wales*, **67**, 420–28 (1933).—The previous work of Fenner, Day, and Shepherd, Houldsworth and Cobb, Braesco, and others is summarized. The authors obtain both α- and β-cristobalite as intermediate forms between amorphous silica (vitreous silica or silica gel) and tridymite. On standing for several months, β cristobalite showed α-tridymite lines. H.H.S.

Diffraction of X-rays in the crystalline substance and X-ray structural analysis. V. LINITSKY. *Ukrain. Chem. Jour.*, **9** [1], 46–60 (1934). S.I.P.

Equilibria of iron and oxygen with silicon, calcium, and phosphorus. F. KANZ, E. SCHEIL, AND E. H. SCHULZ. *Arch. Eisenhüttenwesen*, **8**, 67–74 (1934).—Microscopic investigations at room temperature were carried out on the equilibria in the iron corners of the diagrams of iron and oxygen with silicon, calcium, and phosphorus. The following equilibria with iron were found in the system Fe–Si–O: 3 regions of 2 phases each, and 2 regions of 3 phases each. The cross-sections Fe–Fe_2SiO_4 and $FeSiO_3$ are quasi binary. The α-mixed crystal, in equilibrium with ferrous oxide, shows an upper limit of 0.6% Si and, in equilibrium with fayalite, of 2.5% Si. Results obtained in the system Fe–Ca–O agree well with those of former observers. Quasi binary cross-sections and equilibria are presented for the system Fe–P–O. Presence of the phosphate $Fe_2P_2O_7$ increases the rate of decomposition of ferrous oxide. Slag intrusions in steel include ferrous oxide, fayalite, silica, calcium orthoferrite, lime, and the phosphate $Fe_2P_2O_7$. W.M.C.

Glassy state, a fourth state of matter? H. SALMANG. *Naturwissenschaften*, **21** [21–23], 391–92 (1933).—S. reviews theories of prominent investigators concerning the state of aggregation in glass. He believes that in view of the characteristics of glass it is necessary to assign it to a realm apart from that of the other three states of aggregation. L.T.B.

Granular composition as a characteristic of finely divided technical materials. H. W. GONELL. *Chem. Fabrik*, **6** [22], 227–33 (1933).—For valuating a dust-like (dispersed) technical material, the knowledge of its granular composition is essential. Sifting is usable only for grains larger than 60μ for determining the granular composition or grain size. Among the mechanical methods wind sifting is suitable for all materials which can be dispersed into their primary particles without the aid of liquids. Elutriation and sedimentation are chiefly used in ceramics and in the study of soils. For other materials, elutriation is practical only when they are not sensitive to water. Sedimentation has a much wider field of application. Microscopic measurements are generally suitable only for qualitative investigations and for orientation on the limiting of grain sizes. The X-ray determination of particle sizes is used in special cases in highly dispersed materials. M.V.K.

Heat conduction in crystals. A. PAPAPETRU. *Physik. Z.*, **35** [13], 527–28 (1934).—Equations are presented for heat conduction in crystals. These equations may be applied to all types of crystals. W.M.C.

Identification of crystalline substances by means of the petrographic microscope. T. N. MCVAY. *Bull. Amer. Ceram. Soc.*, **13** [10], 255–60 (1934).

Melting-point determinations of many metallurgical slags. AXEL WEJNARTH. *Metall & Erz*, **31** [4], 72–77 (1934).—Melting-point determinations were made on

compositions in the systems, $FeO–SiO_2$, $FeO–CaO–SiO_2$, $FeO–MnO–CaO–SiO_2$, $FeO–MnO–CaO–Al_2O_3–SiO_2$, $FeO–MnO–CaO–Al_2O_3–MgO–SiO_2$. Measurements are tabulated for the various compositions. The melting-point determinations were made in connection with the measurement of the electric conductivity of the slags. L.T.B.

Method of determination of alkalis in rocks according to the J. Lawrence Smith method. W. VAN TONGEREN. *Z. anorg. allgem. Chem.*, **218** [3], 252 (1934).—T. recommends grinding the weighed sample of rock in alcohol as well as adding alcohol when the NH_4Cl and $CaCO_3$ are mixed with it. The danger of losing any of the powder following such treatment is minimized. L.T.B.

Methods used in glaze production. JAKOB KLUG. *Keram. Rund.*, **42** [23], 281–83; [24], 296–98; [26], 321–22 (1934).—Numerous methods of calculating various glazes are discussed. M.V.K.

Mineral coloration. JOSEF HOFFMANN. *Z. anorg. allgem. Chem.*, **219** [2], 197–202 (1934).—On subjecting certain minerals to radium radiation, color changes often occur in the minerals. The causes of these changes in some quartz minerals and in rock salt are discussed. L.T.B.

Physicochemical fundamentals of the modern silicate industry. W. EITEL. *Angew. Chem.*, **46** [52], 803–10 (1933).—A general review of the physicochemical and mineralogical methods employed for the study of the silicates is given. Most investigation of the silicates to date has been by a determination of equilibrium conditions in the silicate systems, some of which are briefly reviewed. The theories of structure of crystalline silicates as interpreted from space lattice and X-ray crystal measurements are outlined. The meager data concerning the structure of the amorphous silicates and the theories drawn therefrom are reviewed. The significance of the effects resulting from the electrical forces within the individual silicate molecules is discussed. The formation of solvates and their rôle in the physical and chemical behavior of silicates are outlined. Finally, E. reviews the absorption spectra of glasses and the significance of the results in silicate chemistry and physics. L.T.B.

Sorption capacity of clays in connection with their structure. S. S. URAZOVSKY AND M. M. SHTSCHERBAK. *Ukrain. Chem. Jour.*, **8** [2], 155–67 (1934). S.I.P.

Specific heats of CaO, Al_2O_3, $CaO·Al_2O_3$, $3CaO·Al_2O_3$, $2CaO·SiO_2$, $3CaO·SiO_2$, and $2CaO·Al_2O_3·SiO_2$ from 20 to 1500°C. H. ELSNER VON GRONOW AND H. E. SCHWIETE. *Z. anorg. allgem. Chem.*, **216** [2], 185–95 (1933); for abstract see *Ceram. Abs.*, **13** [7], 171 (1934). L.T.B.

Spectra of silicates in the near infra-red. K. WIRTZ. *Physik. Z.*, **35** [16], 649–51 (1934).—Spectra were measured between 7 and 21μ. The different types of silicate spectra are discussed. Groups such as SiO_4, Si_2O_7, etc., may be set in parallel to the radicals of acids, the only differences being that silicate groups form no ions in solutions, and that silicate and oxygen may form compounds in all three dimensions. W.M.C.

System, silicon–aluminum. O. REBUFFAT. *Giorn. chim. ind. applicata*, **16** [5], 213–15 (1934).—R. studied the behavior of mixtures of Si and Al in which Si is in the form of tridymite and Al in the form of Al_2O_3. For equal percentages of Al, the melting points show clearly the influence of the original state of Al; the diagram of Bowen and Greig for this system is modified to adapt it better to actual conditions. Melting points of different mixtures are tabulated; they range from 1710°C for 5% Al_2O_3 to 1970°C for 90% Al_2O_3 in mixtures with tridymite. M.H.

Thermal analysis of clay. A. GRANGER. *Céramique*, **37** [552], 58 (1934).—Critical temperature points of clay may be used as a means of identification. M.H.B.

Thermal and X-ray character of the lattice displacement in zinc oxide. R. FRICKE AND P. ACKERMANN. *Z. anorg. allgem. Chem.*, **214** [2], 177–88 (1933).—Samples of zinc oxide prepared by the dehydration of the crystalline hydroxide show varying heats of solution depending on the temperature of dehydration and the age of the preparations. These differences in energy are interpreted as due to incomplete crystal lattice formation. No evidence was obtained of the existence of other modifications of zinc oxide. L.T.B.

Time-saving method for determining boric acid in arsenic-free borosilicates. WERNER MYLIUS. *Chem.-Ztg.*, **57** [18], 173–75; [20], 194–95 (1934).—One-half gram of the sample is heated in a platinum dish with 1.2 g. KOH and 4.8 g. NaOH at about 480°. Higher temperatures will injure the dish. After about 7 min. the decomposition of the silicate is complete. The residue is dissolved in a total of 75 cc. water and the solution is neutralized with concentrated hydrochloric acid until Congo paper turns blue. By adding 40 cc. of saturated $Ba(OH)_2$ solution all interfering substances except As are removed. The precipitate is dissolved in acid and the precipitation with $Ba(OH)_2$ repeated twice. In the filtrate, $BaCO_3$ forms on standing and is removed. The clear solution is neutralized to methyl red and after the introduction of 50 cc. of inverted sugar sirup, the HBO_3 is titrated with $Ba(OH)_2$ to phenolphthalein neutrality. Results are given to show the accuracy of the method and full details of all the operations. M.V.K.

Viscosity and its expression. I. G. BARR. *Proc. World Petroleum Congr.*, **2**, 508–11 (1933).—Most viscosimeters measure kinematic viscosity and the result is converted into poises, the dynamic units, by multiplying by d. The complications thus introduced, by the variation of d with temperature, have militated against the general use of poises, and it is suggested that the general use of the stokes, the absolute unit of kinematic viscosity, would be more satisfactory. Conversion formulas from Redwood, Saybolt, or Engler readings to stokes are not likely to be accurate at differing temperatures. The use of the absolute unit in specifications will therefore involve the elimination of the commercial units where accuracy is important. Absolute units are usually determined by Ostwald-type viscosimeters. In such, the error due to surface tension may be considerable unless volumes of $\leqslant$ 5 milliliters and mean heads $\leqslant$ 10 cm. are used. II. E. C. BINGHAM. *Ibid.*, pp. 512–14.—As practically all viscosity measurements are relative to a calibrating fluid, agreement on a standard is of the first importance for comparable results in absolute units. Single sample standards, as maintained in the U. S., are unsatisfactory. The viscosity of H_2O at 20°, though known only with an accuracy of 0.5%, is the most suitable. A clear distinc-

tion must be made between viscous and plastic flow. Tentative definitions are given of consistency, of a simple liquid where the ratio of flow to force is constant, and of a "non-Newtonian liquid" where this relation does not hold. Plasticity of a solid is made up of yield value and mobility. Direct measurements of flow are practicable for many solids and are preferable to empirical tests of penetration, etc. (*B.C.A.*)

Vitreous phase of certain ceramic materials. B. Long. *Céramique*, **37** [553], 81–86 (1934).—Dilatation curves of vitreous materials are an index to strains, both permanent and temporary. Several typical curves are given. M.H.B.

Vogel rhodanide reaction for detecting cobalt in the presence of iron. Hugo Ditz and Richard Hellebrand. *Z. anorg. allgem. Chem.*, **219** [1], 97–104 (1934).—A modification of the rhodanide method for the detection of cobalt in the presence of iron is described in which acetone is substituted for the amyl alcohol-ether mixture. The detection of cobalt in the presence of large amounts of iron is facilitated thereby. L.T.B.

Volumetric methods for determining aluminium oxide. N. I. Bogolepov. *Legkie Metallui*, No. 2, pp. 29–31 (1932); abstracted in *Chem. Zentr.*, i, 2315 (1934).—Al_2O_3, NaOH, and Na_2CO_3 can be determined volumetrically with normal HCl in the presence of metanil yellow: $[Al_2O_3 \cdot Na_2O + NaOH + Na_2CO_3] + 11HCl = 2AlCl_3 + 5NaCl + CO_2 + 6H_2O$. In the presence of rosalic acid $[Al_2O_3 \cdot Na_2O + NaOH + Na_2CO_3] + 5HCl = 2Al(OH)_3 + 5NaCl + CO_2$, and with phenolphthalein $[Al_2O_3 \cdot Na_2O + NaOH + Na_2CO_3] + H_2O + 4HCl = 2Al(OH)_3 + 4NaCl + NaHCO_3$. The first titration is done at 40°, the second at 60°. M.V.K.

Water content and distribution of grain size in foundry sands (raw, molding, and core sands). P. Bergmann, W. Claus, and E. Waldschmidt. *Giesserei*, **21** [33–34], 350–52 (1934).—The change of dielectric constant by the humidity content of the dielectric material is used for determining the H_2O content of the sand by comparison with a water-free sand in a condenser. By applying Stokes' law, the distribution of grain size in a sample of sand can be determined by the sedimentation velocity of the sand. The instrument is described and the method illustrated by an example. M.H.

X-ray and colloidal chemical studies on clay. Ulrich Hofmann, Kurd Endell, and Diederich Wilm. *Angew. Chem.*, **47** [30], 539–47 (1934).—An investigation to establish the nature of clays is presented. An extensive number of clay minerals was studied by X-rays, and a series of clays from different localities was classified by the same means. The thermal decomposition of clays was followed by X-ray studies. The colloidal chemical properties of clays were determined by measurement of the absorption and base exchange in clays. The absorption of ions by clays is not a surface force but a chemical process with which plasticity is closely allied. Recently the absorption properties and plasticity of clays have been attributed to an indefinite substance, "allophane," which is classified by the authors as a crystalline compound of definite structure and not an amorphous gel. The plasticity of clays is due to kaolinite crystals and not to an amorphous allophane. The size of the crystals in clays was studied by means of X-rays and photometer curves of the films were obtained, but no definite conclusions could be drawn regarding the relation of crystal size and plasticity. The result of a study of the nature of the base exchange in the crystal lattice is reported. See also *Ceram. Abs.*, **13** [4], 101 (1934). L.T.B.

BOOK REVIEW

Nephelometric Determination of Small Quantities of CaO, MgO, and SO_3 in Silicates. F. I. Perchik and A. S. Lototskaya. Ukrain. Sci. Research Inst. of Bldg. Materials Mineral Origin. Ukrain. State Pub. House, Light Ind., Kharkov, 1934. 19 pp. Price 0.75 R. As a result of the research work the conclusions were as follows: (1) CaO, MgO, and SO_3 in silicates may be estimated with enough accuracy by the nephelometric method; (2) the average duration of each determination separately varies from 30 to 40 min., when the average duration for a weight method is a working day. S.I.Perkal

BOOKS

Laboratory Manual of Inorganic Chemistry with Introduction to Qualitative Analysis. 4th ed. J. B. Ekeley. John Wiley & Sons, Inc., New York, 1934. 293 pp. Price $2.00. Reviewed in *Jour. Amer. Chem. Soc.*, **56** [9], 2016 (1934). F.G.H.

Quantitative Chemical Analysis for Beginning Students. G. M. Smith. 3rd ed. Macmillan Co., New York, 1934. 199 pp. Price $2.25. Reviewed in *Jour. Amer. Chem. Soc.*, **56** [9], 2015 (1934); see also *Ceram. Abs.*, **13** [3], 74 (1934). F.G.H.

Volumetric Analysis. H. P. Stark. William Wood & Co., Baltimore, Md., 1934. 259 pp. Price $3.00. Reviewed in *Jour. Amer. Chem. Soc.*, **56** [9], 2016 (1934). F.G.H.

PATENT

Preparation of fluosilicates. International Refining Co., Ltd. (L. Brann). Brit. 415,972, Sept. 12, 1934.

General

American Ceramic Society defends ceramic engineering. Ross C. Purdy and H. H. Horner. *Bull. Amer. Ceram. Soc.*, **13** [10], 281–82 (1934).

Cellular response of lymph nodes to suspensions of crystalline silica and to two varieties of sericite introduced through lymphatics. Cecil K. Drinker, Madeleine E. Field, and Philip Drinker. *Jour. Ind. Hyg.*, **16** [5], 296–99 (1934).—Certain lymph nodes of two dogs were injected with two types of sericite and with crystalline silica for control. After 10 and 12 days, the dogs were killed and the nodes containing sericite showed changes similar to those which had received silica. It may be inferred that dusts containing either of these sericites will, upon inhalation, react as does crystalline silica. Illustrated. E.J.V.

Classification as engineers of graduates of collegiate ceramic schools. Editorial. *Bull. Amer. Ceram. Soc.*, **13** [10], 261 (1934).

Correct the little faults; watch your plant efficiency gain. FRED M. BURT. *Ceram. Ind.*, **23** [4], 200–202 (1934).—To increase enamel plant efficiency the first essential is good housekeeping. Illustrated. E.J.V.

Factors intervening in the aging of clay. S. R. HIND. *Claycraft*, **6**, No. 8; abstracted in *Bldg. Sci. Abs.*, **6**, No. 11; *Rev. mat. constr. trav. pub.*, No. 296, p. 97*B* (1934).—The value of weathering of clay depends mainly on the type of clay subjected to it. Observations made on a series of clays subjected to weathering are discussed. M.V.K.

Importance of ceramic trade papers to ceramic progress. EDITORIAL. *Bull. Amer. Ceram. Soc.*, **13** [10], 261 (1934).

Mica-feldspar separation by flotation. G. GERTH AND H. ZIERGIEBEL. *Z. Ver. deut. Ing.*, **78** [36], 1064 (1934).—A short description of the method, the fluids used, the fineness of the raw materials, and the results obtained as expressed in percentage separation is presented. L.T.B.

Microscopic detection of quartz in dust. C. SORGENFREI. *Zeiss Nachr.*, **3**, 25–31 (1933); abstracted in *Chem. Zentr.*, **i**, 3219 (1933).—Dust is collected on the stage of a konimeter which is coated with albuminous glycerin. This is dried with absolute alcohol. The dust is then photographed in air, alcohol, and in tetraline. M.V.K.

Mortar mix made from waste clay proves practical in application. H. R. STRAIGHT. *Brick Clay Rec.*, **85** [3], 94–95 (1934).—Results of a series of tests made on mortar mix are presented and specifications for using this new by-product in the clay industry are given. See also *Ceram. Abs.*, **13** [11], 293 (1934). E.J.V.

Science and progress in industry. I. W. HEISENBERG. *Stahl & Eisen*, **54** [29], 749–52 (1934).—The principles underlying the structure of the atom are outlined. Application of scientific progress to industry is demonstrated by the development of ferromagnetic materials. **II.** P. GOERENS. *Ibid.*, **54** [29], 752–60 (1934).—The importance of research in the steel and allied industries is emphasized. Examples demonstrating financial success from research and development work are (1) replacing charcoal by mineral coal in blast furnaces, (2) introducing the converter process by Bessemer, (3) developing materials of special electric properties, (4) treating steel according to theoretical considerations regarding the atomic structure of metals, etc. Problems to be solved in the future are direct reduction of iron ores, influencing the properties of steels by minute foreign additions to the melt, and correlation of the atomic structure of steel and its most important properties. Rules for scientific work are outlined, and a close contact is emphasized between the research laboratory and the plant. W.M.C.

Silicosis. R. R. SAYERS. *U. S. Pub. Health Repts.*, **49**, 595–602 (1934); abstracted in *Ind. Hyg. Abs.*, **16** [5], 100 (1934).—The definition of silicosis as recently set up by the Committee on Pneumoconiosis of the Industrial Hygiene Section of the American Public Health Association is as follows: a disease due to the breathing of air containing silica (SiO_2), characterized anatomically by generalized fibrotic changes and the development of miliary nodulation in both lungs, and clinically by shortness of breath, decreased chest expansion, lessened capacity to do work, absence of fever, increased susceptibility to tuberculosis (some or all of which symptoms may be present), and by characteristic X-ray findings. An excellent short review of the history of silicosis is given. E.J.V.

Silicosis. ANON. *Crushing and Grinding*, **2**, 222 (1934).—A general résumé is presented of papers and discussions read before the American Institute of Mining and Metallurgical Engineers. X-ray technique has been developed by means of which the disease can be detected at an early stage. Adequate ventilation is the best preventative. L. U. Gardner stated that silica is a definite body-cell poison, and he doubted the theory put forward by W. R. Jones (*Ceram. Abs.*, **13** [9], 246 (1934)) that sericite is the cause of silicosis. (*T.C.S.E.*)

Silicosis and its incidence in gold mines. Y. V. S. IYER. *Analyst*, **59**, 403 (1934).—The recent statement that the dust from the Au-bearing quartz rock of the Kolar Gold Fields, India, has not produced any cases of silicosis is false. (*C.A.*)

Uses of sodium silicates in the ceramic industries. WILLIAM STERICKER. *Bull. Amer. Ceram. Soc.*, **13** [10], 264–66 (1934).

Values derived from high-school ceramics. ARNOLD BOOKHEIM. *Bull. Amer. Ceram. Soc.*, **13** [10], 271–73 (1934).

BOOK REVIEW

Control of Industrial Research. ANON. Published by the Policyholders Service Bureau of the Metropolitan Life Insurance Company, New York. 27 pp. Free. The report includes (1) organization of the research department, (2) origin and authorization of research projects, (3) preparation of cost estimates, (4) research budget, (5) standardization of research procedure, (6) cost keeping and control, and (7) review and reconsideration of research projects. Various methods of establishing the definite place of the research activities within an organization and their place in the budget are discussed. Those interested in the administration of research activities will find this publication helpful and interesting. M.C.SHAW

BOOKS

Report of the Fuel Research Board for the Year ended March 31, 1933. DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. H. M. Stationery Office, London, 1933. 140 pp. Price 2s 6d. Reviewed in *Mech. Eng.*, **56** [3], 188 (1934). F.G.H.

Report for the Year 1932–1933. DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. H. M. Stationery Office, London, 1934. 189 pp. Price 3s. Reviewed in *Mech. Eng.*, **56** [5], 316 (1934).—The work done by all the governmental research institutions and the licensed research associations is reviewed, with lists of the publications that describe the results more fully. F.G.H.

Soil Analysis. Handbook of Physical and Chemical Methods. C. H. WRIGHT. Thomas Murby and Co., London, 1934. 236 pp. Price 12s 6d. Reviewed in *Jour. Amer. Chem. Soc.*, **56** [6], 1430 (1934). F.G.H.

Tables of Integrals and Other Mathematical Data. H. B. DWIGHT. Macmillan Co., New York, 1934. 222

pp. Price $1.50. Reviewed in *Mech. Eng.*, **56** [3], 189 (1934). F.G.H.

Technical Thermodynamics (Technische Thermodynamik). W. SCHULE. Translated from the German by E. W. Geyer, University of Glasgow. Isaac Pitman and Sons, Ltd., London, and Pitman Publishing Corp., New York, 1934. 627 pp. Price $10.00. Reviewed in *Power*, **78** [3], 157 (1934). F.G.H.

PATENTS

Ceramic masses. WALTER BLOCH. Ger. 552,750, March 10, 1934. Dense masses are obtained without using quartz or feldspar by sintering a eutectic mixture of clay and talcum. Thus, a mixture of Zr ore clay slurry and raw talcum is fired. Substances such as kaolin, powdered marble, or pyrolusite may be used. See also Fr. 738,222, *Ceram. Abs.*, **12** [7], 270 (1933). (*C.A.*)

Process of making a fused amorphous ceramic composition. T. S. CURTIS (Vitrefrax Corp.). U. S. 1,973,408, Sept. 11, 1934.